Total Ore Processing Integration and Management

2nd Quarterly Technical Progress Report
01 October - 31 December 2003

written by

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Abstract

This report outlines the technical progress achieved for project DE-FC26-03NT41785 (Total Ore Processing Integration and Management) during the period 01 October through 31 December of 2003.

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Executive Summary

Work in Progress: Data Management

The initial data flow sheet for the Minntac Mine was constructed during last quarter. This is being used in the analysis of the ore segregation tests. The initial data flow sheet for the Hibtac Mine will be formulated during the next quarter.

Work in Progress: Data Mining

Historical data from both mines were collected and analyzed during the second quarter. Eloranta and Associates compared powder factor to crusher performance, mill throughput, and mill power consumption for Hibtac Mine, summarized in the figures below. Also, pit production data for the years 1999 through the beginning of 2003 have been turned over to project personnel.

Work in Progress: Ore Segregation Tests

Two segregation tests were conducted at Minntac Mine prior to this quarter, in which haul trucks bringing ore from the active mining benches were directed to different crushers by the dispatcher based on a pre-calculated silica liberation index called the A factor. The A factor predicts the amount of grinding needed to liberate a given amount of silica. It is calculated with data collected from grinding tests of exploration core samples. Silica liberation is an essential task of iron ore processing.

Ore from which silica was predicted to be difficult to extract (high A factor) was sent to one line of the processing plant, and ore for which silica extraction was predicted to be easy (low A factor) was sent to the other line. The two streams were crushed separately, then each was ground in separate rod mills and passed through four separation stages (rougher, cobber, finisher, and cleaner) before being re-combined to enter the froth flotation tanks where the excess silica is removed.

Work in Progress: Orebody Models

The two block models of the Minntac Mine is being expanded to include new liberation characteristics and ore oxidation. Work also was initiated in the second quarter to add blasthole drill performance characteristics to the model.

The Minntac model is being used to help identify areas in the mining sequence that have unfavorable rock characteristics, by sectioning it along the mining benches, plotting these characteristics, and crosschecking them against the current mine plan.

Future Work

The first fragmentation study at Hibtac Mine will take place at the start of the next quarter. Its goal is to begin to understand the relationship between performance of the autogenous grinding (AG) mills and the powder factor used to blast the ore (see Data Mining section above). Since the largest rock fragments act as the grinding media, the size distribution of the feed significantly impacts mill performance. The test program eventually will include fragmentation measurements (with WipWare support), AG mill performance measurements, and blast measurements (with MinEx support).

Introduction

Now that the first quarterly report has set down the preceding history of the research, this second quarterly report discusses the activities of the project team during the period 1 October through 31 December 2003.

Work in Progress

Data Management

The initial data flow sheet for the Minntac Mine was constructed during last quarter. This is being used in the analysis of the ore segregation tests. The initial data flow sheet for the Hibtac Mine will be formulated during the next quarter.

Additional sources of data at both mines continue to be identified and tapped.

Data Mining

Historical data from both mines were collected and analyzed during the second quarter. Eloranta and Associates compared powder factor to crusher performance, mill throughput, and mill power consumption for Hibtac Mine, summarized in the figures below. Also, pit production data for the years 1999 through the beginning of 2003 have been turned over to project personnel.

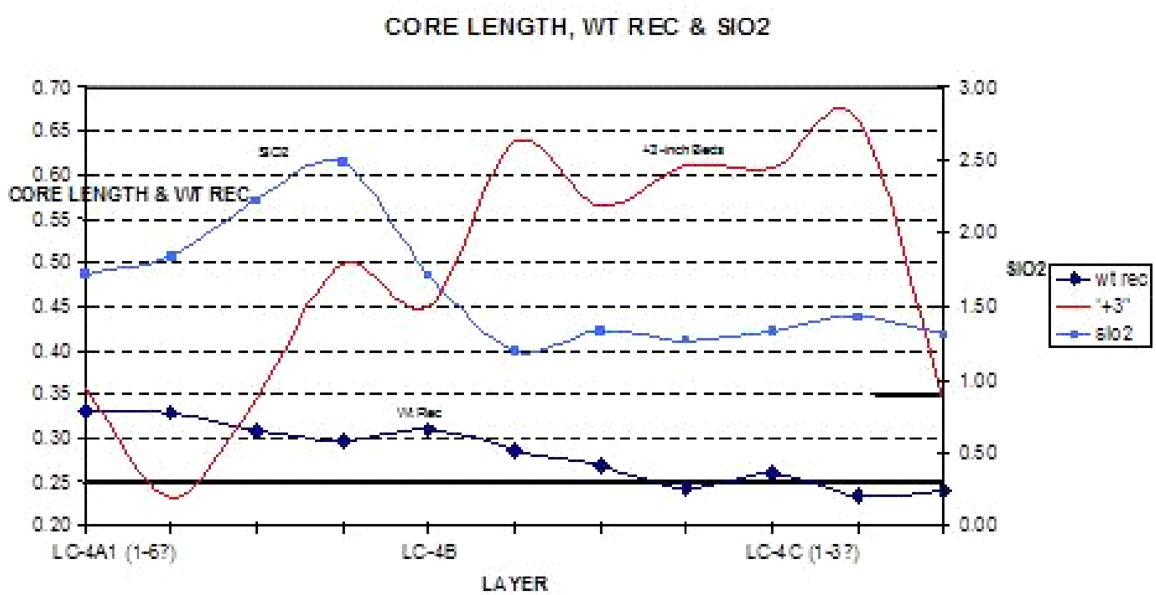

Figure 1. Hibtac Mine geologic formation versus core recovery and silica content. The two mines in this study use different labels for the ore formations, so both methods are used in this graph.

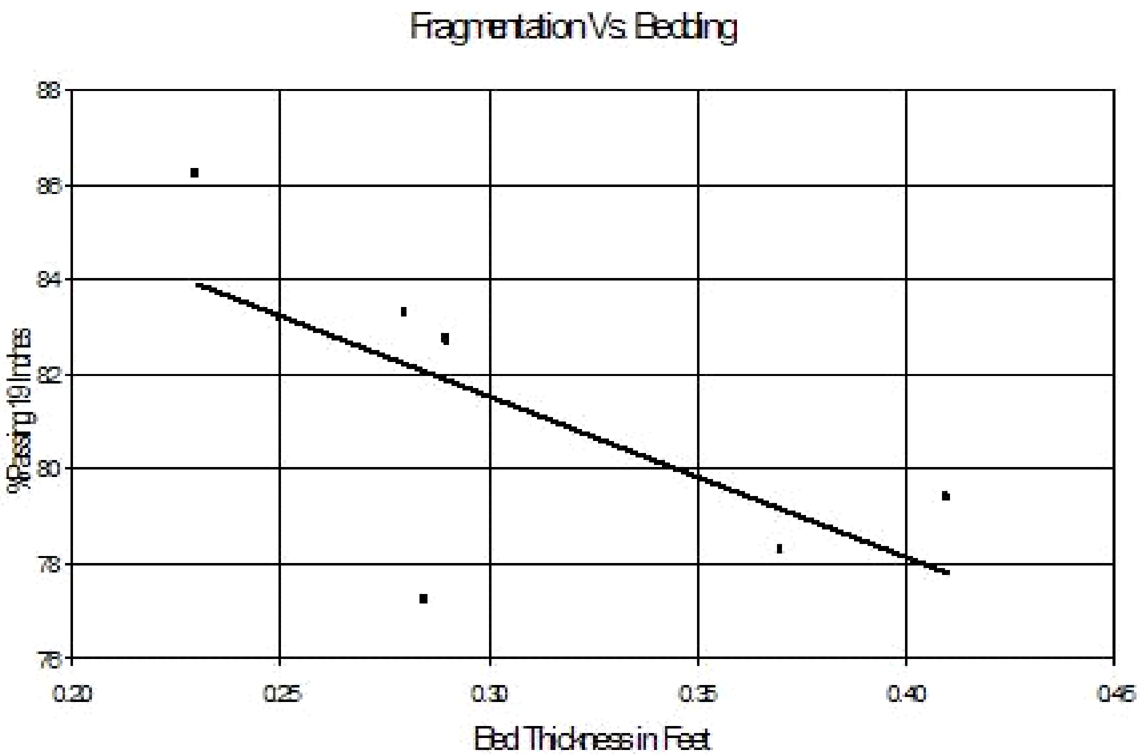

Figure 2. Hibtac Mine formation thickness versus primary fragmentation (blasting) results.

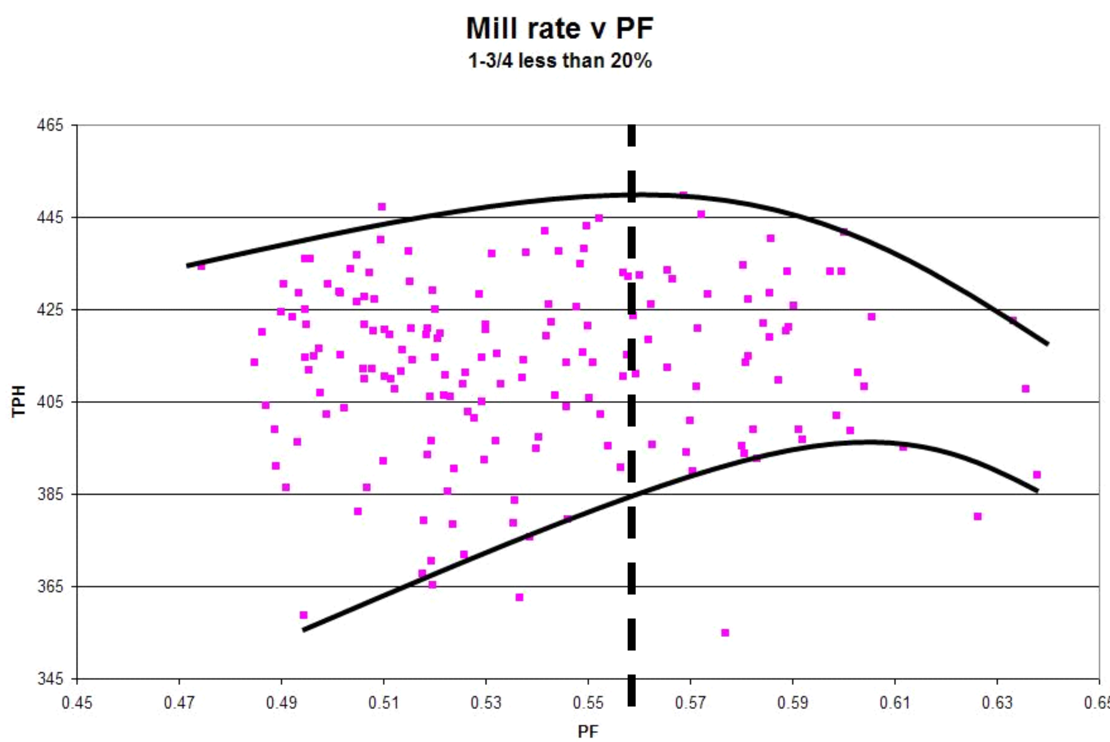

Figure 3. Hibtac Mine powder factor versus mill throughput. This is the basis for selecting the recommended powder factor (dashed line) for the first ore segregation test at Hibtac Mine, planned for next quarter.

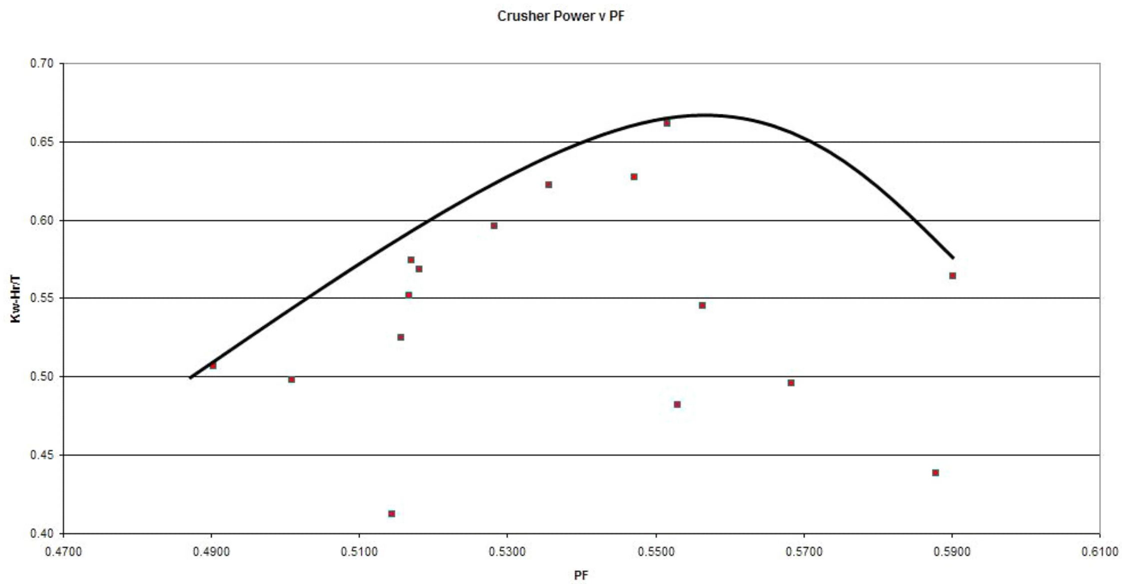

Figure 4. Sixteen months of powder factor versus normalized primary crusher power draw at Hibtac Mine. Note that the crusher can apply more energy to the feed as the ROM size decreases, but very fine blast fragmentation causes the crusher to act as a chute. This causes the reduced power draw at higher powder factors.

Ore Segregation Tests

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Ore from which silica was predicted to be difficult to extract (high A factor) was sent to one line of the processing plant, and ore for which silica extraction was predicted to be easy (low A factor) was sent to the other line. The two streams were crushed separately, then each was ground in separate rod mills and passed through four separation stages (rougher, cobber, finisher, and cleaner) before being re-combined to enter the froth flotation tanks where the excess silica is removed.

Separating the ore by its A factor was expected to segregate it directly by silica concentration and indirectly by other, geologically and mineralogically related elements. Magnetic iron, alumina, magnesia, calcium oxide, and manganese concentrations, in addition to silica, are monitored daily in the Minntac Mill. Other parameters also are monitored; their responses to the segregation tests are being examined now.

Table 1. Data comparisons between the low-A factor and the high-A factor ore processing lines before, during, and after the Minntac Mine ore segregation test #1, at 90% confidence level.

STATISTICALLY SIGNIFICANT	Low Line Rod Mill <> High Line Rod Mill				
DIFFERENCES (space)	Al	Ca	Mg	Mn	SiO2
Before Test				X	
During Test	X	X			X
After Test					

	Low Line <> High Line (Met Report)							
STATISTICALLY SIGNIFIC	RMF	Concent.	C-Tails	F-Tails	RMF	RMF	RMF	RMF
DIFFERENCES (space)	mag Fe	mag Fe	mag Fe	mag Fe	khw/t	-3/4"	-1/2"	3/4 to 1/2"
Before Test					X	X		X
During Test				X	X	X		
After Test			X	X	X			

The results of basic statistical analysis of the first ore segregation test are summarized in Tables 1 and 2, and in the accompanying data tables and figures (Appendices). This analysis tested the hypothesis that two average data values are equal, at the 90% confidence level, using the ***t*** statistic. The strong conclusion, that they are not equal, indicates that a statistically significant difference exists between the two; these are indicated in the tables by X's. The variances of the distributions being compared are unknown; they are assumed to be equal since the same processes and instruments were used to measure all of them. In addition, the analysis was repeated with the variances assumed unequal. There was little change in the results. These results are not reported here, since this analysis is less rigorous.

In the rod mill feed (i.e., the mine output from the benches, after passing through the crusher) and in the coarse tailings from the rougher, the amount of magnetic iron is the same in both ore streams, at 90% confidence. By the time the finely ground ore has gone through the cobber, finisher, and cleaner, and has reached the re-combination point, that is no longer the case: more magnetic iron remains in the fine tailings from the high-A factor line than those from the low-A factor line. The high-A factor line also appeared at first look to require more power to grind its ore, but examination of pre- and post-test data shows that this is normally the case. It may be due to differences in make/model of the equipment and variation in maintenance schedules, in addition to physical differences in the ore.

The two crushed ore streams as fed into the rod mills do contain different amounts of silica at 90% confidence, as expected, but they also appear to contain different amounts of alumina and calcium oxide. This may be due to the mineralogy of the orebody, in which calcium and aluminum deposition is correlated with silica deposition. The reported measurement variances, an independent check of the hypothesis-testing results, indicate that the alumina result may not be significant. These results are being compared to the results of the second ore segregation test (currently underway). The second test consists of a greater number of data points and thus is expected to narrow the confidence limits (Appendix).

As mentioned, to check the results and the process by which they are reached, data from the two ore processing streams were analyzed also before and after the segregation test. In most cases there were no significant differences, but in a few cases there were. For example, the manganese content of the ore being fed into the rod mill which later ground the low-A factor ore was higher than for the ore going into the rod mill which later ground the high-A factor ore. Also, the power draw for one of the two crushers is always higher than for the other. These, and similar comparison results, indicate that steady state may not be an accurate assumption for the combined ore stream constituents outside the time boundary of the segregation tests. They also point out where differences may exist that are due not to variation in measured ore stream constituents, but rather to other causes such as equipment.

Table 2. Data comparisons with the same parameter before, during, and after the Minntac Mine ore segregation test #1.

STATISTICALLY SIGNIFICANT	Low Line Rod Mill Feed (R2S)					High Line Rod Mill Feed (R3S)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2	Al	Ca	Mg	Mn	SiO2
Before <> During				X		X	X			X
Before <> After	X					X			X	X
During <> After				X		X	X		X	X

STATISTICALLY SIGNIFICANT	Float Feed (FLF)					Float Feed (FFD)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2	Al	Ca	Mg	Mn	SiO2
Before <> During					X				X	X
Before <> After					X			X	X	X
During <> After					X			X		X

STATISTICALLY SIGNIFICANT	Float Concentrate (FC3)					Float Tails (FLT)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2	Al	Ca	Mg	Mn	SiO2
Before <> During							X	X	X	X
Before <> After			X		X		X	X		X
During <> After										X

STATISTICALLY SIGNIFICANT	Column Float Feed (CFD)					Column Float Concentrate (CFC)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2	Al	Ca	Mg	Mn	SiO2
Before <> During					X					X
Before <> After			X		X			X		X
During <> After			X		X			X		X

STATISTICALLY SIGNIFICANT	Column Float Tails (CFF)					Filter Cake #2 (FC2)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2	Al	Ca	Mg	Mn	SiO2
Before <> During			X		X		X	X		X
Before <> After			X		X		X			X
During <> After		X	X		X		X	X		

STATISTICALLY SIGNIFICANT	Filter Cake #3 (FC3)				
DIFFERENCES (time)	Al	Ca	Mg	Mn	SiO2
Before <> During					
Before <> After			X		X
During <> After					

The most noteworthy result of comparing temporal change in parameter values is that silica content, more than any other element, varies outside the time limits of the test. This is true less often for magnesium and calcium.

Orebody Models

The two block models of the Minntac Mine is being expanded to include new liberation characteristics and ore oxidation. Work also was initiated in the second quarter to add blasthole drill performance characteristics to the model.

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Future Work

The first fragmentation study at Hibtac Mine will take place at the start of the next quarter. Its goal is to begin to understand the relationship between performance of the autogenous grinding (AG) mills and the powder factor used to blast the ore (see Data Mining section above). Since the largest rock fragments act as the grinding media, the size distribution of the feed significantly impacts mill performance. The test program eventually will include fragmentation measurements (with WipWare support), AG mill performance measurements, and blast measurements (with MinEx support).

Both mines monitor the performance of the blast hole production drills. At Minntac Mine, the drill performance data will be added to the segregation tests. At Hibtac Mine, the data will be part of the fragmentation study. A sophisticated image collection and analysis system is being prepared by project partner WipWare Inc. to be installed at the Hibtac Mine primary crusher next quarter to better quantify the results of the Hibtac segregation tests.

Additonal refinement of the Minntac orebody model is required and will progress throughout the project. A model of the Hibtac Mine is being planned; its creation will begin once the exploration data has been sent to us.

The remainder of the data available for the first Minntac Mine ore segregation test and the data from the second Minntac segregation test will be analyzed during the third quarter. The data from the first Hibtac Mine ore segregation test will be collected and analysis will begin as soon as possible.

Research Partners

Queens University has expressed interest in joining the project as a Research Partner.

Appendix: Data Summary from Minntac Mine Ore Segregation Test #1

	Low Line Rod Mill Feed (R2S)					High Line Rod Mill Feed (R3S)					Float Feed (FLF)				
AVERAGES	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2
Before Test	0.0525	0.265	0.228	0.0775	5.19	0.0475	0.288	0.235	0.0900	5.13	0.0580	0.353	0.273	0.0860	5.50
During Test	0.0425	0.238	0.200	0.1100	4.39	0.0625	0.190	0.233	0.1000	5.55	0.0609	0.265	0.245	0.1082	5.09
After Test	0.0360	0.276	0.216	0.0760	4.77	0.0360	0.276	0.220	0.0780	4.70	0.0512	0.359	0.279	0.0847	5.24
STD DEVIATIONS															
Before Test	0.0096	0.0173	0.0206	0.0050	0.437	0.0096	0.0171	0.0173	0.0082	0.306	1.706	0.1978	0.0616	0.0946	0.0704
During Test	0.0096	0.0435	0.0356	0.0216	0.697	0.0096	0.0216	0.0171	0.0082	0.294	0.899	0.2213	0.0604	0.1045	0.0962
After Test	0.0055	0.0611	0.0288	0.0089	0.400	0.0055	0.0251	0.0122	0.0084	0.178	2.495	0.1420	0.0894	0.0606	0.0639
90% CONFIDENCE LIMITS															
Before Test	0.0113	0.0204	0.0243	0.0059	0.514	0.0113	0.0201	0.0204	0.0096	0.360	0.776	0.0899	0.0280	0.0430	0.0320
During Test	0.0113	0.0512	0.0419	0.0254	0.820	0.0113	0.0254	0.0201	0.0096	0.345	0.491	0.1209	0.0330	0.0571	0.0526
After Test	0.0052	0.0582	0.0275	0.0085	0.382	0.0052	0.0239	0.0117	0.0080	0.169	1.056	0.0601	0.0378	0.0257	0.0271

	Float Feed (FFD)					Float Concentrate (FC3)					Float Tails (FLT)				
AVERAGES	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2
Before Test	0.036667	0.233	0.168	0.061	4.05	0.057705	3.59	1.11	0.0734	3.63	0.153	0.668	0.736	0.1553	22.08
During Test	0.049167	0.155	0.146	0.338	3.43	0.067174	3.61	1.12	0.0907	3.66	0.189	0.787	0.921	0.2075	25.42
After Test	0.046111	0.222	0.356	0.303	3.68	0.055323	3.61	1.13	0.0715	3.66	0.164	0.750	0.914	0.1669	24.49
STD DEVIATIONS															
Before Test	2.83	0.248	0.117	0.129	0.0728	1.63	0.0759	0.0644	0.0880	0.0852	0.636	0.1281	0.0440	0.0714	0.0800
During Test	2.57	1.688	0.135	0.107	0.0521	1.60	0.0898	0.0524	0.0832	0.0894	0.602	0.1167	0.0437	0.0532	0.0435
After Test	3.68	1.264	0.157	0.139	0.0655	1.43	0.0932	0.0509	0.0904	0.0796	0.616	0.1200	0.0534	0.0716	0.0501
90% CONFIDENCE LIMITS															
Before Test	1.29	0.113	0.0530	0.0587	0.0331	0.348	0.0162	0.0138	0.0188	0.0182	0.289	0.0582	0.0200	0.0324	0.0364
During Test	1.33	0.875	0.0700	0.0555	0.0270	0.396	0.0223	0.0130	0.0206	0.0221	0.312	0.0605	0.0226	0.0276	0.0225
After Test	1.51	0.518	0.0643	0.0572	0.0269	0.303	0.0198	0.0108	0.0192	0.0169	0.270	0.0526	0.0234	0.0314	0.0220

	Column Float Feed (CFD)					Column Float Concentrate (CFC)					Column Float Tails (CFF)				
AVERAGES	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2
Before Test	0.121	0.389	0.504	0.116	15.1	0.105	0.372	0.454	0.1119	12.14	0.166	0.439	0.631	0.135	22.5
During Test	0.139	0.333	0.543	0.141	15.5	0.115	0.297	0.455	0.1309	11.37	0.197	0.367	0.694	0.170	24.2
After Test	0.127	0.433	0.601	0.123	15.4	0.103	0.415	0.510	0.1124	11.23	0.183	0.515	0.812	0.154	24.7
STD DEVIATIONS															
Before Test	0.784	0.170	0.0644	0.1163	0.0872	0.985	0.145	0.0698	0.0983	0.0562	0.470	0.163	0.0597	0.0823	0.0483
During Test	0.724	0.191	0.0591	0.0995	0.0501	0.933	0.253	0.0774	0.0780	0.0628	0.559	0.130	0.0493	0.0789	0.0474
After Test	0.888	0.187	0.0548	0.0790	0.0504	1.199	0.141	0.0732	0.0629	0.0541	0.543	0.162	0.0622	0.0872	0.0567
90% CONFIDENCE LIMITS															
Before Test	0.344	0.0743	0.0282	0.0510	0.0382	0.432	0.064	0.0306	0.0431	0.0246	0.206	0.0716	0.0262	0.0360	0.0212
During Test	0.396	0.1043	0.0323	0.0543	0.0273	0.510	0.138	0.0423	0.0426	0.0343	0.324	0.0753	0.0286	0.0458	0.0275
After Test	0.364	0.0768	0.0225	0.0324	0.0207	0.508	0.060	0.0310	0.0266	0.0229	0.230	0.0687	0.0263	0.0369	0.0240

AVERAGES	Filter Cake #2 (FC2) ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2	Filter Cake #3 (FC3) ICP Al	ICP Ca	ICP Mg	ICP Mn	ICP SiO2
Before Test	0.0659	3.52	1.09	0.0727	3.62	0.0577	3.59	1.11	0.0734	3.63
During Test	0.0691	3.56	1.12	0.0911	3.72	0.067174	3.61	1.12	0.0907	3.66
After Test	0.0544	3.46	1.09	0.0717	3.72	0.055323	3.61	1.13	0.0715	3.66
STD DEVIATIONS										
Before Test	1.51	0.0898	0.0622	0.0995	0.0712	1.63	0.0759	0.0644	0.0880	0.0852
During Test	1.68	0.0721	0.0584	0.0899	0.0640	1.60	0.0898	0.0524	0.0832	0.0894
After Test	2.44	0.0709	0.0522	0.1133	0.0796	1.43	0.0932	0.0509	0.0904	0.0796
90% CONFIDENCE LIMITS										
Before Test	0.318	0.0189	0.0131	0.0209	0.0150	0.348	0.0162	0.0138	0.0188	0.0182
During Test	0.417	0.0179	0.0145	0.0223	0.0158	0.396	0.0223	0.0130	0.0206	0.0221
After Test	0.483	0.0140	0.0103	0.0224	0.0158	0.303	0.0198	0.0108	0.0192	0.0169

	S-trend General Values							Step 1&2, S-trend					Step 3, S-trend			
AVERAGES	IND TOT	FLF SiO2	FLF -270M	amine lb/ton	FLF DTREC	FL,TLS SiO2	FLF -DT	NOLA targ	NOLA comp	filter cake	line pellets	pellet trains	NOLA targ	NOLA comp	filter cake	line pellets
Before Test	5.66	5.41	85.1	0.135	95.1	22.9	1.358	3.89	3.90	3.62	4.20	4.19	3.95	3.97	3.63	4.22
During Test	5.47	5.25	85.8	0.119	95.2	24.2	1.409	4.04	4.02	3.71	4.21	4.24	3.94	3.92	3.68	4.24
After Test	5.44	5.24	85.1	0.126	95.6	25.0	1.811	3.89	3.90	3.69	4.22	4.23	3.87	3.86	3.62	4.19
STD DEVIATIONS																
Before Test	0.314	0.461	1.387	0.0238	0.384	2.20	0.378	0.0772	0.0872	0.0974	0.0570	0.0674	0.0488	0.0872	0.0457	0.0742
During Test	0.252	0.280	0.905	0.0341	0.447	3.31	0.110	0.0700	0.0870	0.1162	0.1621	0.0697	0.0498	0.0769	0.0836	0.1314
After Test	0.136	0.306	1.448	0.0233	0.466	2.57	1.119	0.0617	0.0861	0.0914	0.0790	0.0794	0.0925	0.0929	0.0880	0.1002
90% CONFIDENCE LIMITS																
Before Test	0.143	0.210	0.631	0.0108	0.175	1.20	0.172	0.0351	0.0397	0.0443	0.0259	0.0333	0.0222	0.0397	0.0208	0.0337
During Test	0.156	0.174	0.561	0.0211	0.277	2.05	0.068	0.0434	0.0540	0.0721	0.1005	0.0512	0.0309	0.0477	0.0518	0.0815
After Test	0.042	0.095	0.449	0.0072	0.153	0.80	0.347	0.0192	0.0267	0.0284	0.0245	0.0272	0.0287	0.0288	0.0273	0.0311

	Step 1&2, Mine-indicated Values									
AVERAGES	wt% Fe	SiO2	mag Fe	COIL	HIS	UC	A-factor	IBC	L3-4	L1-2
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	28.7	4.84	20.2	18.2	7.94	1.15	1.37	2.29	62.3	25.3
After Test	--	--	--	--	--	--	--	--	--	--
STD DEVIATIONS										
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	1.17	0.310	0.825	2.20	6.80	1.04	0.165	3.07	12.9	9.04
After Test	--	--	--	--	--	--	--	--	--	--
90% CONFIDENCE LIMITS										
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	0.638	0.170	0.451	1.20	3.72	0.990	0.0900	1.91	7.02	4.94
After Test	--	--	--	--	--	--	--	--	--	--

	Step 3, Mine-indicated Values									
AVERAGES	wt% Fe	SiO2	mag Fe	COIL	HIS	UC	A-factor	IBC	L3-4	L1-2
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	26.4	6.64	18.6	12.7	47.7	4.60	2.04	3.57	24.0	26.0
After Test	--	--	--	--	--	--	--	--	--	--
STD DEVIATIONS										
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	1.20	0.206	0.855	2.88	9.76	2.38	0.250	4.49	8.75	15.6
After Test	--	--	--	--	--	--	--	--	--	--
90% CONFIDENCE LIMITS										
Before Test	--	--	--	--	--	--	--	--	--	--
During Test	0.656	0.112	0.467	1.57	5.33	10.6	0.137	2.78	4.78	8.50
After Test	--	--	--	--	--	--	--	--	--	--

	Step 1&2, Met Report								Step 3, Met Report							
AVERAGES	RMF mag Fe	Con mag Fe	Crs Tails mag Fe	Fne Tails mag Fe	RMF khw/t	RMF -3/4"	RMF -1/2"	RMF 3/4 to 1/2"	RMF mag Fe	Con mag Fe	Crs Tails mag Fe	Fne Tails mag Fe	RMF khw/t	RMF -3/4"	RMF -1/2"	RMF 3/4 to 1/2"
Before Test	18.3	65.3	2.53	1.11	10.7	96.7	82.7	14.0	17.9	65.3	2.67	1.22	11.8	97.9	81.3	16.7
During Test	19.1	65.7	2.63	1.05	10.7	96.3	80.1	16.2	17.8	65.7	2.75	1.44	12.3	97.4	79.7	17.7
After Test	20.0	65.5	2.74	1.13	11.8	96.9	80.3	16.5	20.0	65.6	2.85	1.27	13.1	97.7	80.9	16.8
STD DEVIATIONS																
Before Test	0.922	0.154	0.104	0.055	0.304	0.507	0.769	1.17	0.396	0.154	0.139	0.148	0.203	1.158	2.244	1.507
During Test	1.412	0.278	0.103	0.077	0.331	0.365	1.64	1.74	0.730	0.278	0.196	0.100	0.309	0.460	1.733	1.279
After Test	0.783	0.170	0.052	0.061	0.205	0.573	2.51	2.48	0.591	0.111	0.108	0.117	0.265	0.990	1.254	0.336
90% CONFIDENCE LIMITS																
Before Test	0.879	0.146	0.099	0.053	0.290	0.483	0.733	1.12	0.378	0.146	0.133	0.141	0.194	1.104	2.14	1.44
During Test	1.346	0.265	0.098	0.073	0.316	0.348	1.56	1.66	0.696	0.265	0.187	0.095	0.294	0.439	1.65	1.22
After Test	0.747	0.162	0.049	0.058	0.196	0.546	2.39	2.36	0.695	0.131	0.127	0.138	0.312	1.165	1.48	0.395

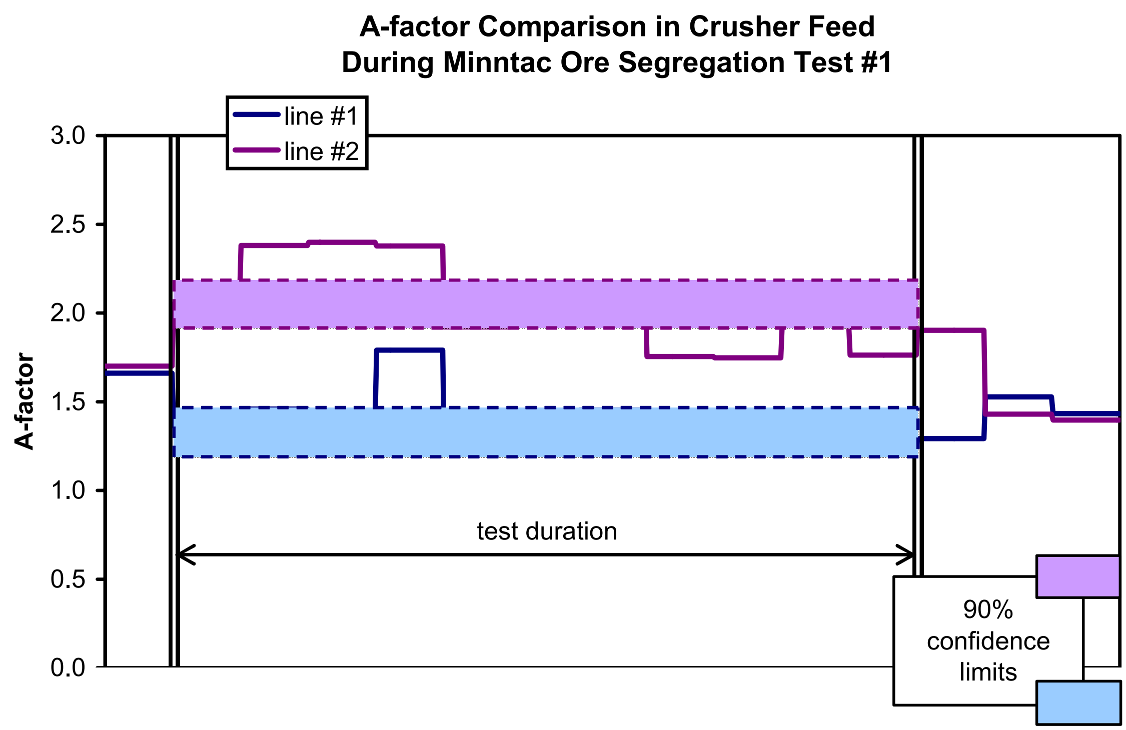
Terms and abbreviations:

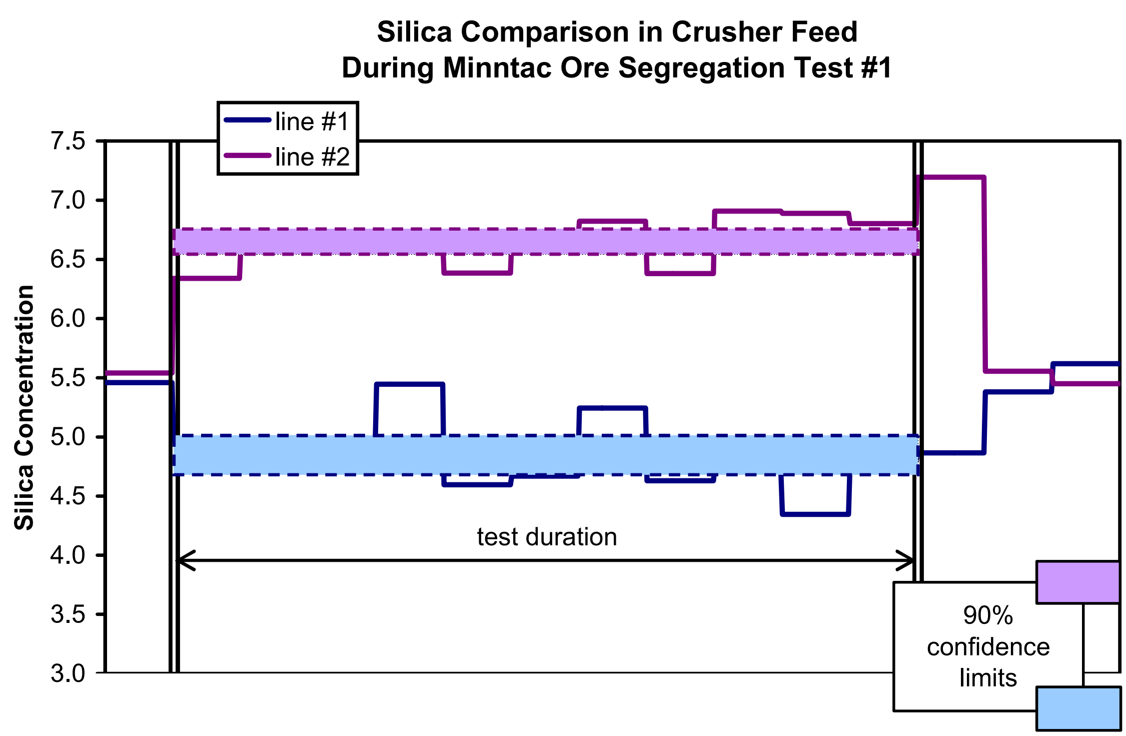
RMF	rod mill feed
Con	concentrate
Crs	coarse
Fne	fine
Mag Fe	magnetic iron content
kwh/t	kilowatt-hours/ton
NOLA	nuclear on-line analyzer
FLF	flotation cell feed
ICP	inductively coupled plasma analysis
SiO2	silica
UC	Upper Chert formation
HIS	high-silica portion of UC
IBC	inter-bedded chert portion of UC
L1-2	Lower Slate layers 1 and 2
L3-4	Lower Slate layers 3 and 4
IND TOT	indicated total iron
TLS	tailings

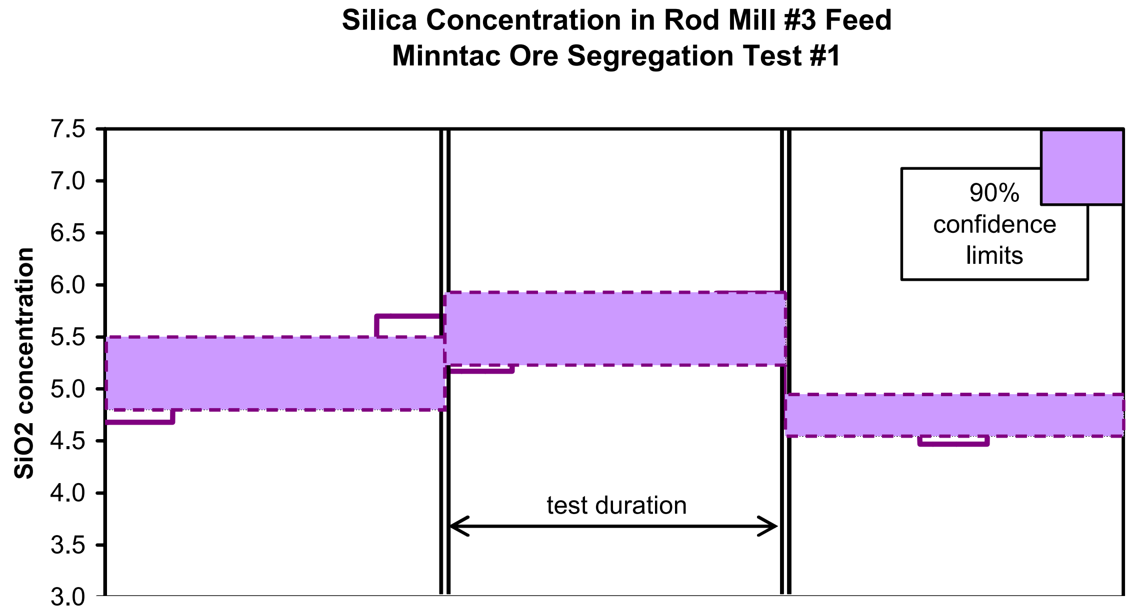
Rod mill 2 and Step 1&2 refer to the low-A factor line. Rod mill 3 and Step 3 refer to the high-A factor line.

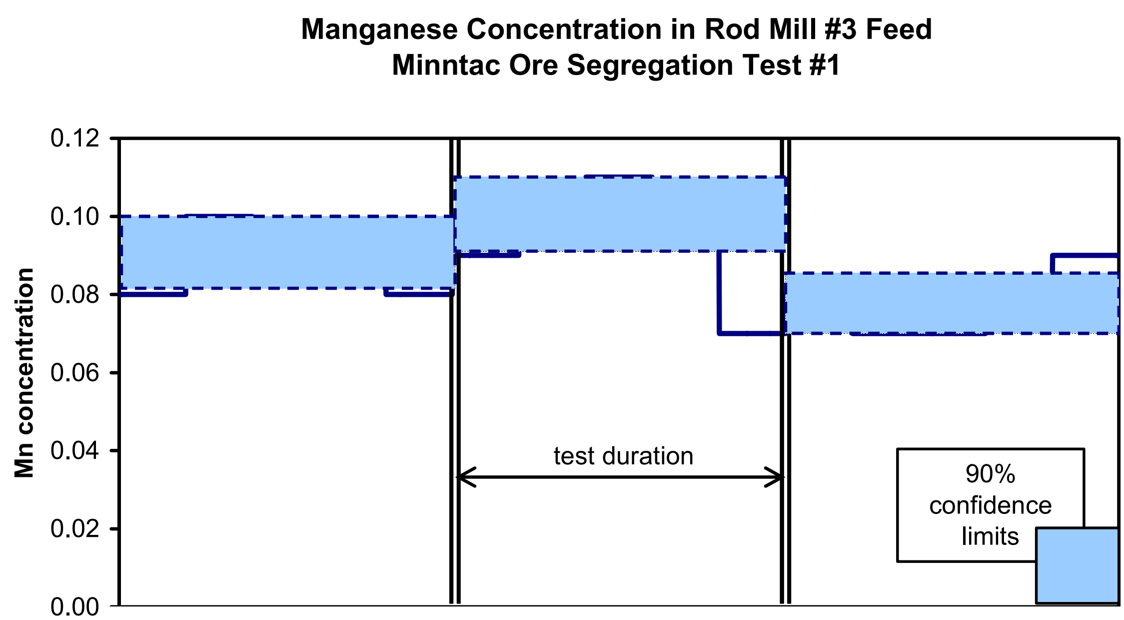
Appendix: Charts from Minntac Mine Ore Segregation Test #1

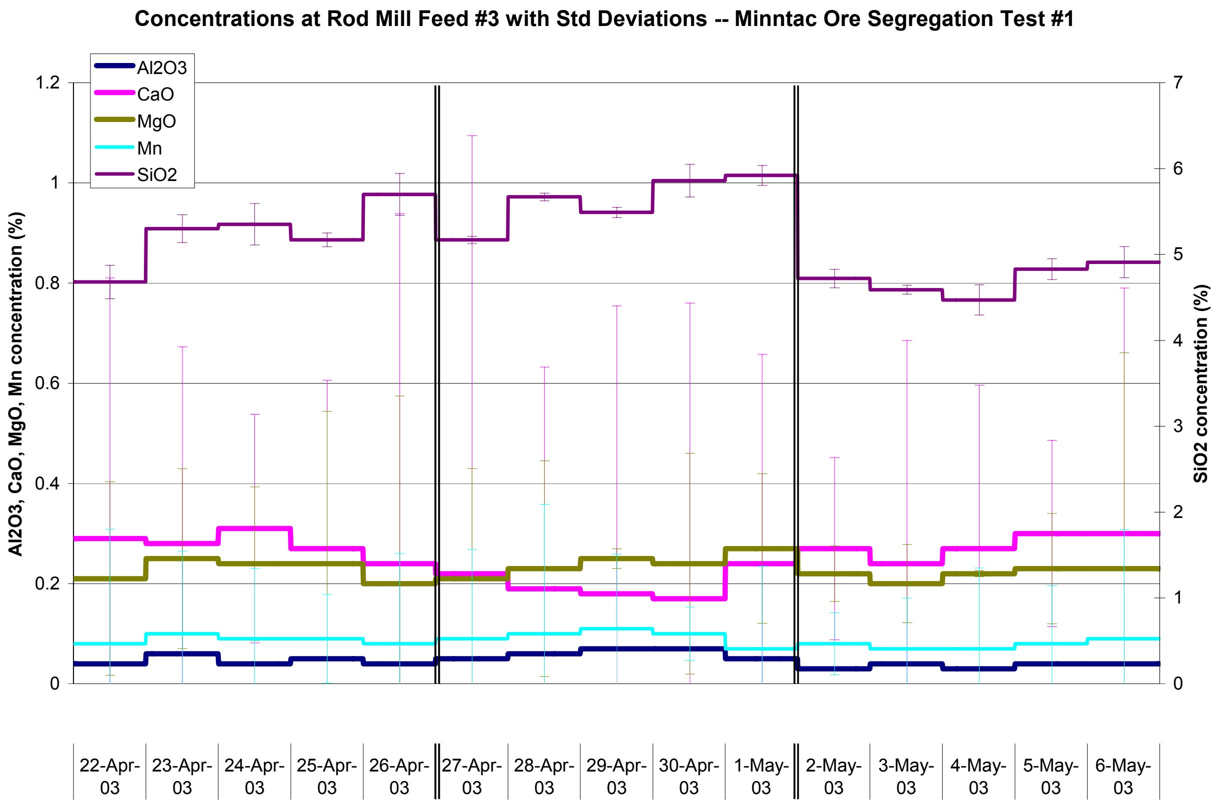
The following charts lay out the data collected during the first ore segregation test at Minntac Mine. The error bars show instrument measurement error.

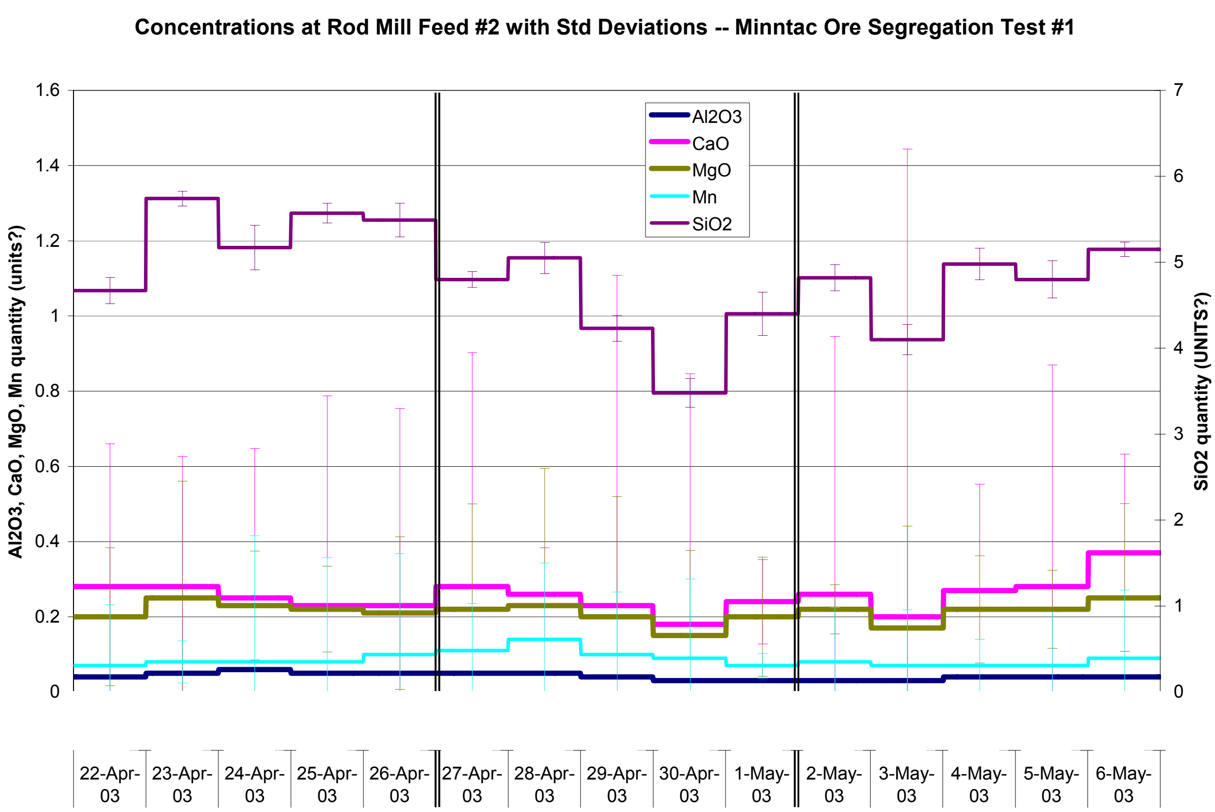




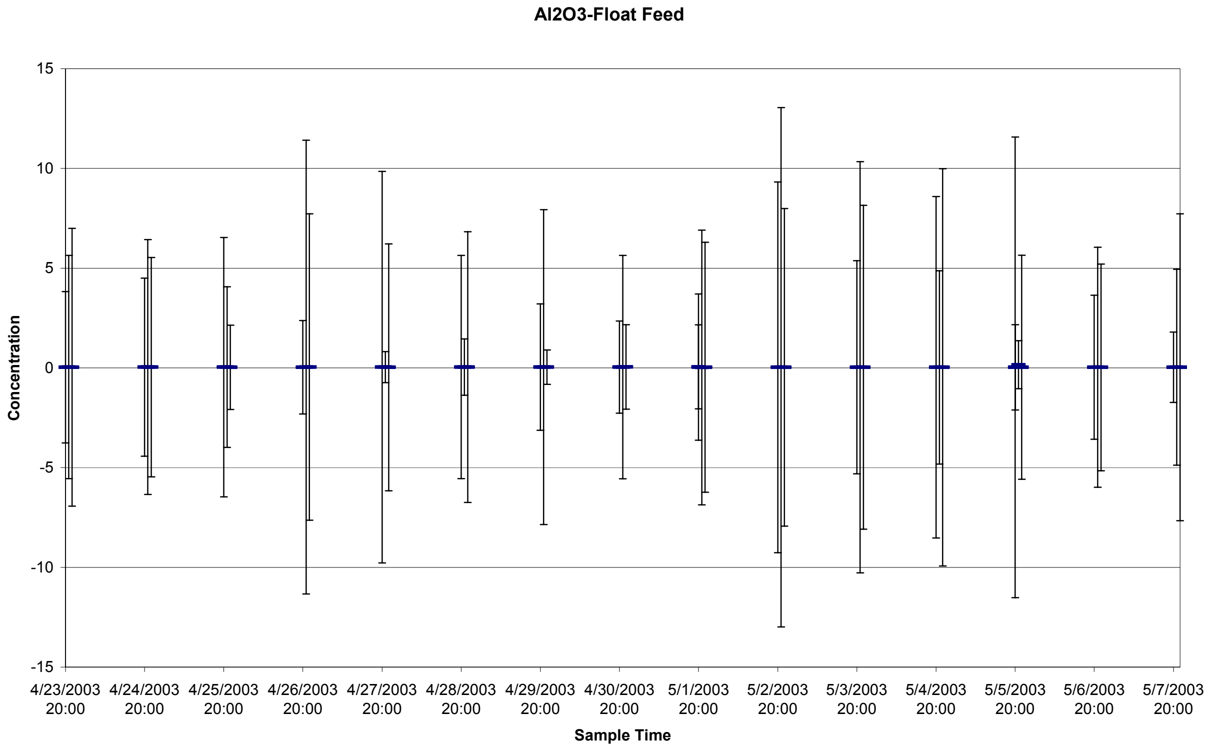

Silica Concentration in Rod Mill #3 Feed
Minntac Ore Segregation Test #1
SiO2 concentration
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
90% confidence limits
test duration

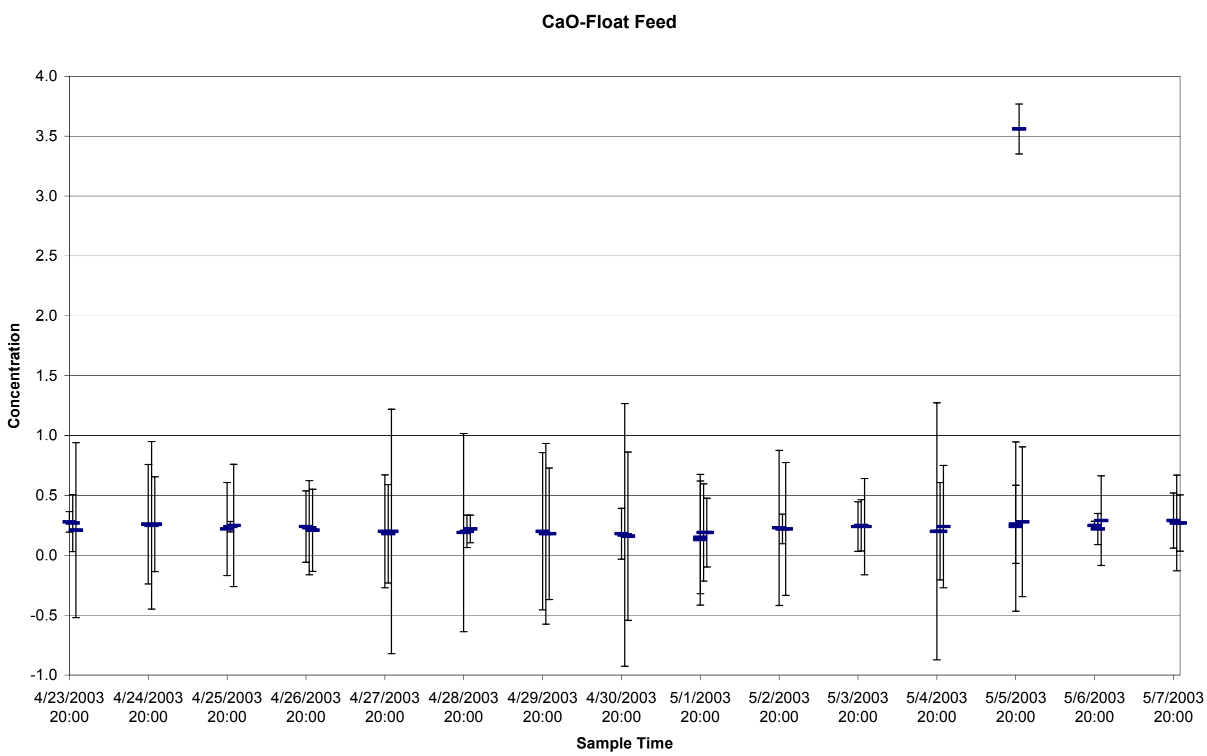

Manganese Concentration in Rod Mill #3 Feed
Minntac Ore Segregation Test #1
Mn concentration
0.12
0.10
0.08
0.06
0.04
0.02
0.00
test duration
90% confidence limits

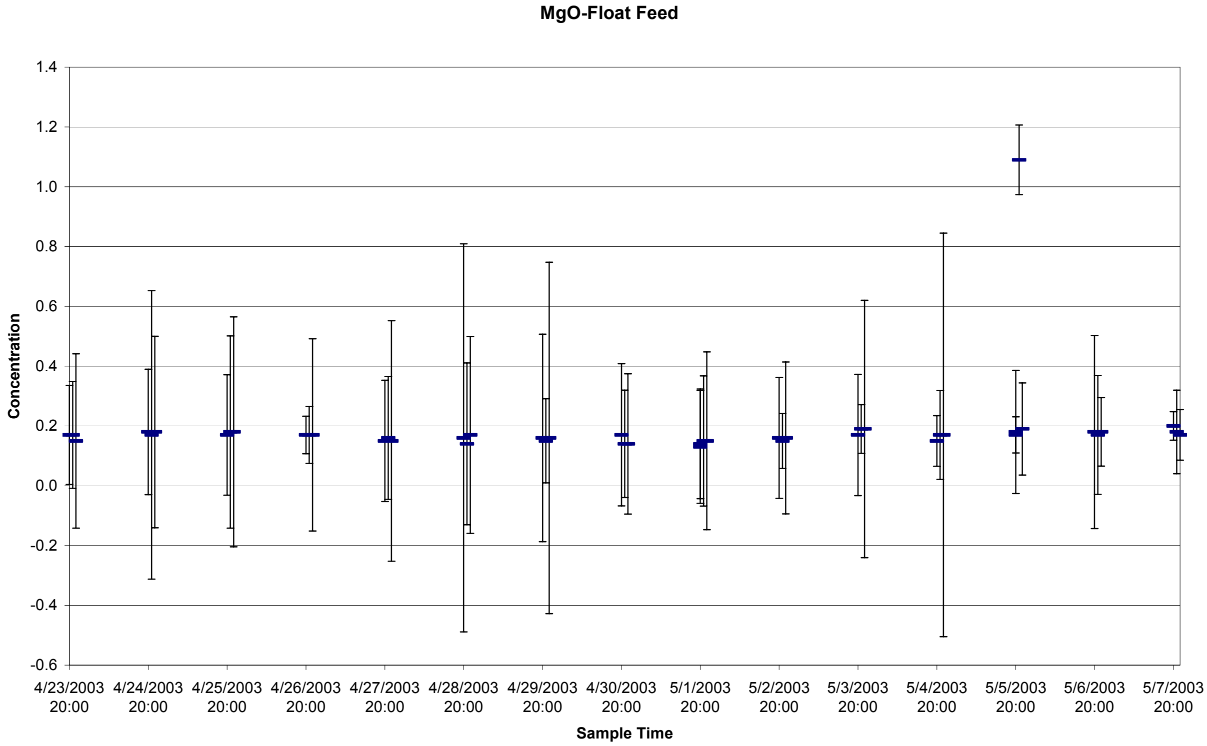

Concentrations at Rod Mill Feed #3 with Std Deviations -- Minntac Ore Segregation Test #1
Al2O3
CaO
MgO
Mn
SiO2
Al2O3, CaO, MgO, Mn concentration (%)
SiO2 concentration (%)
22-Apr-03
23-Apr-03
24-Apr-03
25-Apr-03
26-Apr-03
27-Apr-03
28-Apr-03
29-Apr-03
30-Apr-03
1-May-03
2-May-03
3-May-03
4-May-03
5-May-03
6-May-03

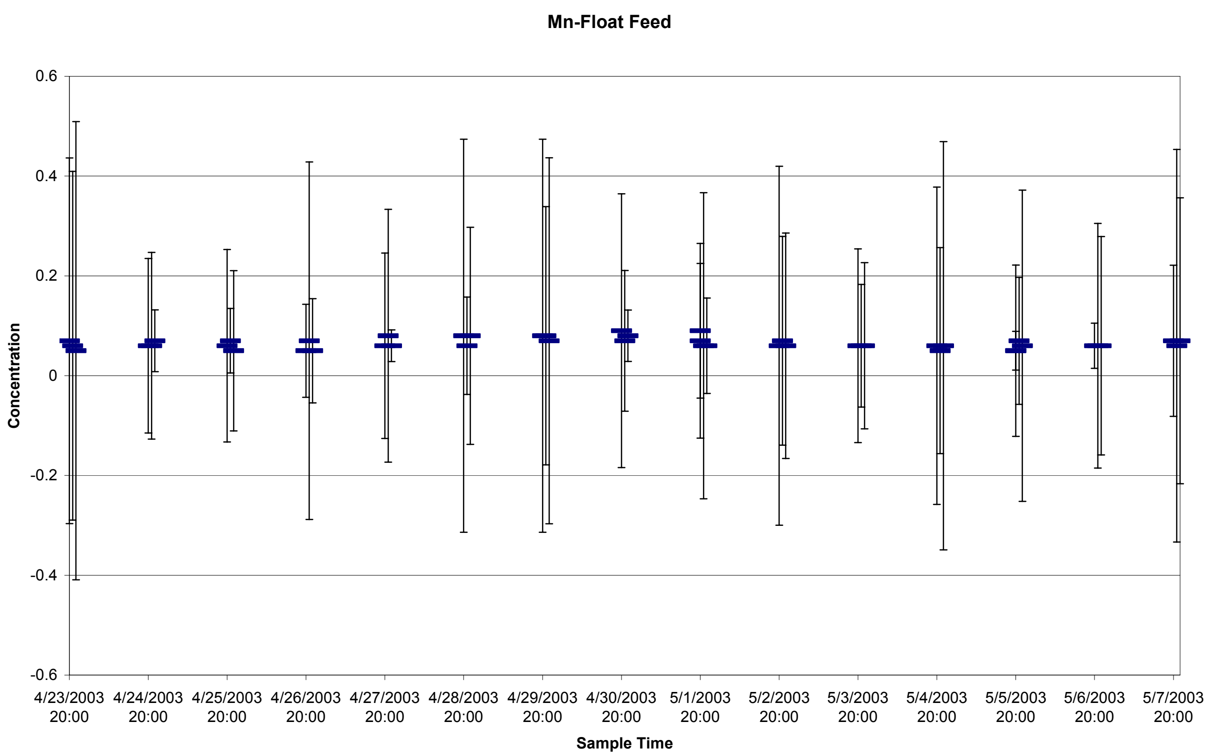

Concentrations at Rod Mill Feed #2 with Std Deviations -- Minntac Ore Segregation Test #1
Al2O3
CaO
MgO
Mn
SiO2
Al2O3, CaO, MgO, Mn quantity (units?)
SiO2 quantity (UNITS?)
22-Apr-03
23-Apr-03
24-Apr-03
25-Apr-03
26-Apr-03
27-Apr-03
28-Apr-03
29-Apr-03
30-Apr-03
1-May-03
2-May-03
3-May-03
4-May-03
5-May-03
6-May-03

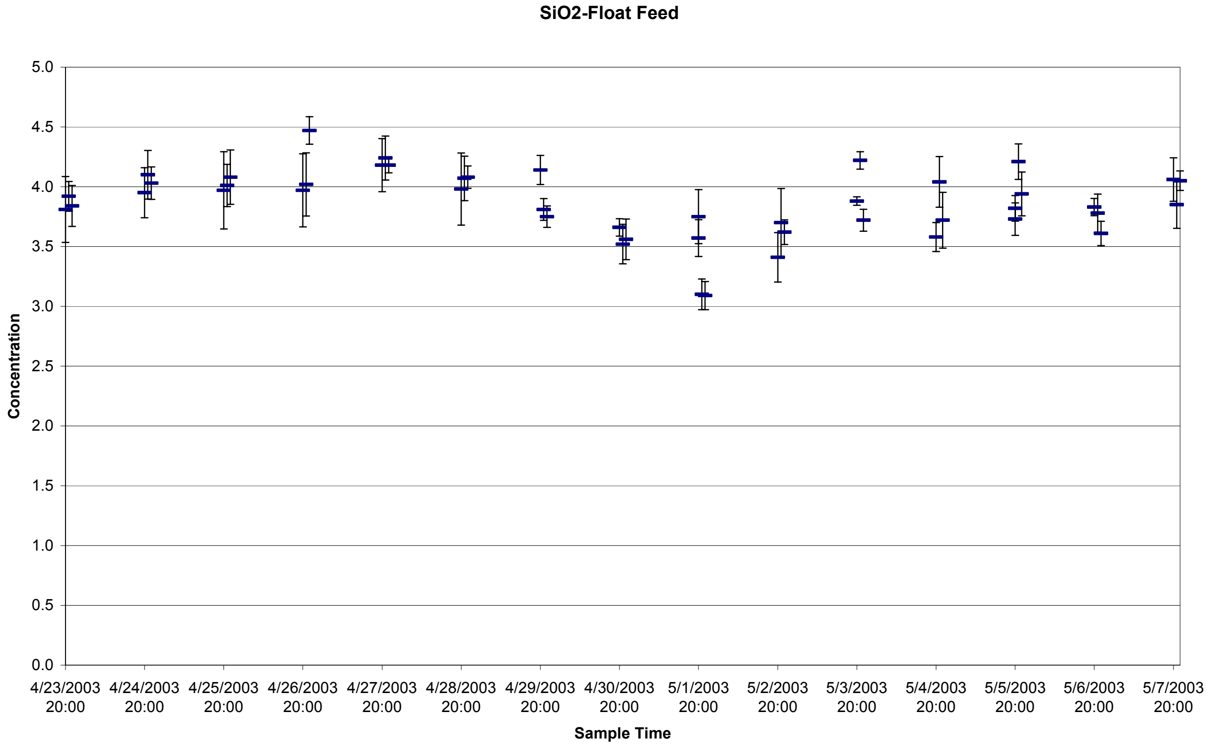
One monitor of the feed to the flotation cells:



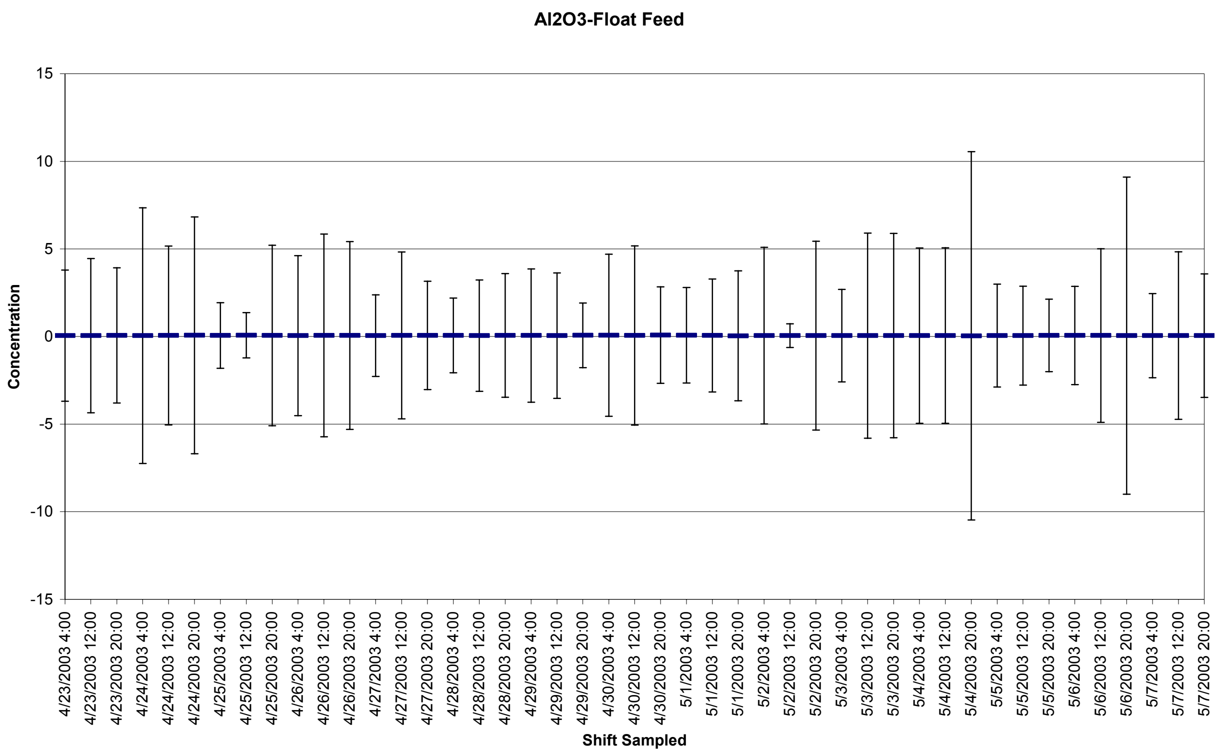


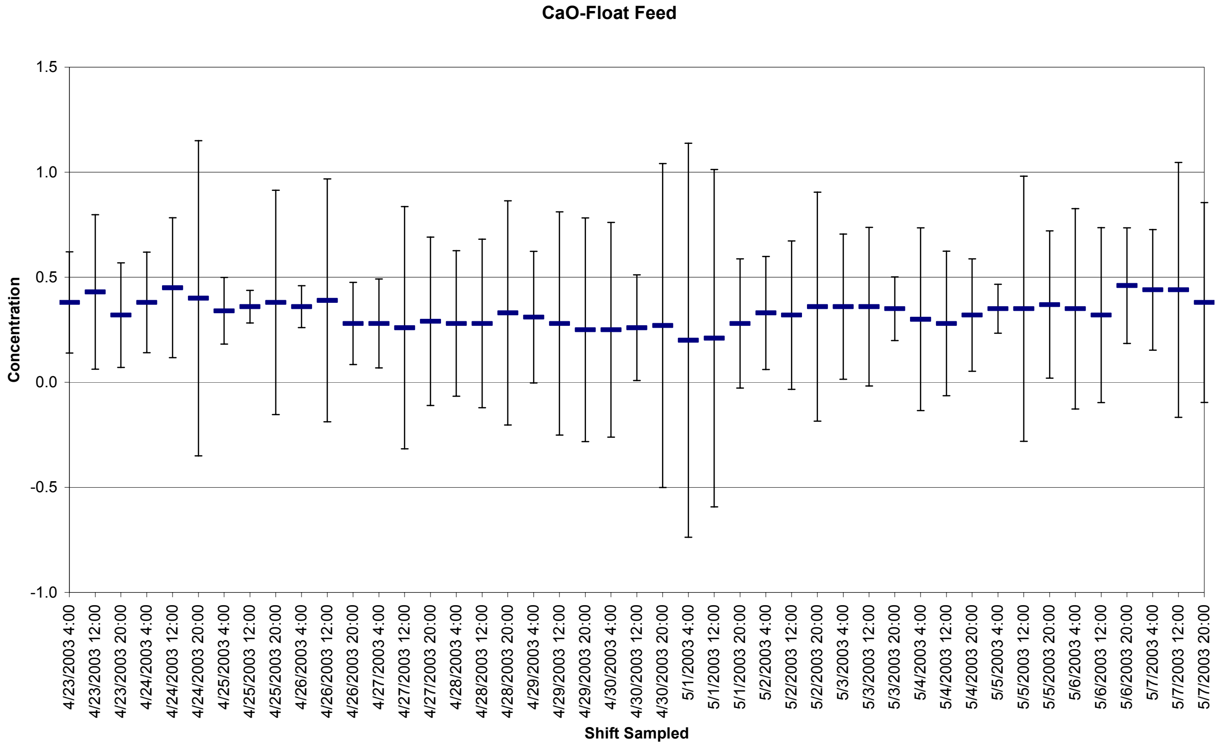

MgO-Float Feed
Concentration
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
4/23/2003 20:00
4/24/2003 20:00
4/25/2003 20:00
4/26/2003 20:00
4/27/2003 20:00
4/28/2003 20:00
4/29/2003 20:00
4/30/2003 20:00
5/1/2003 20:00
5/2/2003 20:00
5/3/2003 20:00
5/4/2003 20:00
5/5/2003 20:00
5/6/2003 20:00
5/7/2003 20:00
Sample Time

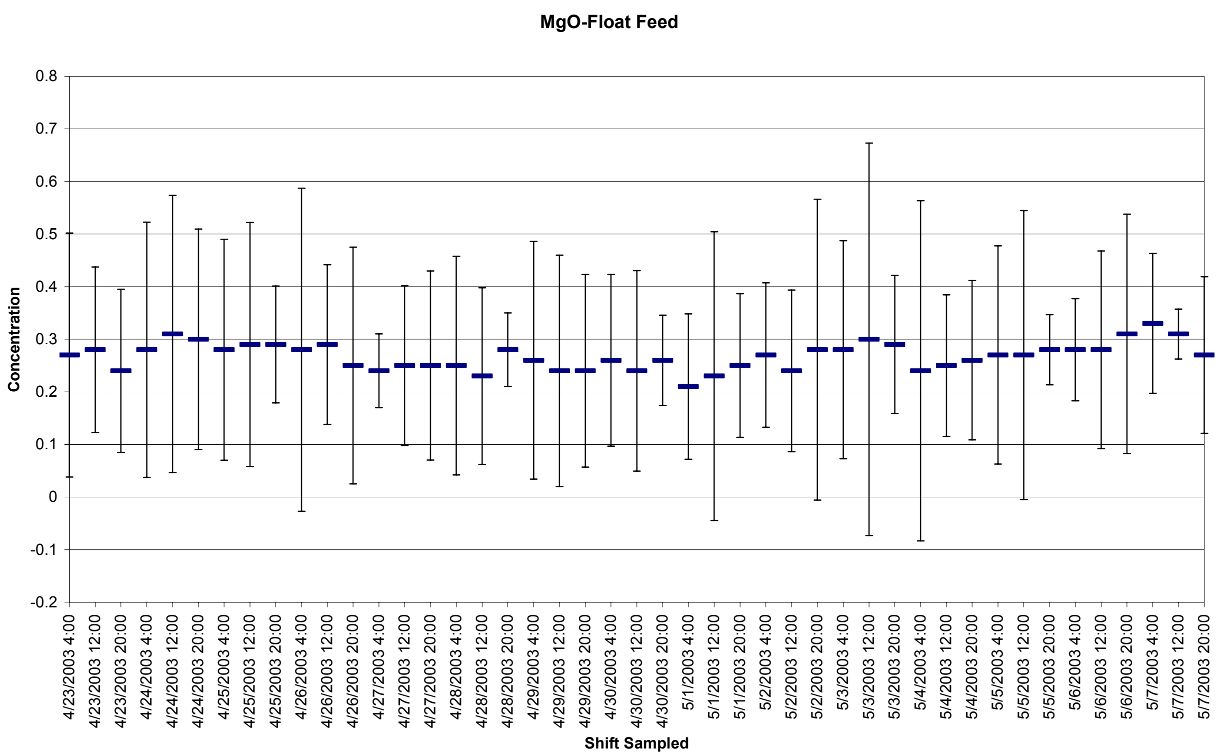

Mn-Float Feed
Concentration
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
4/23/2003 20:00
4/24/2003 20:00
4/25/2003 20:00
4/26/2003 20:00
4/27/2003 20:00
4/28/2003 20:00
4/29/2003 20:00
4/30/2003 20:00
5/1/2003 20:00
5/2/2003 20:00
5/3/2003 20:00
5/4/2003 20:00
5/5/2003 20:00
5/6/2003 20:00
5/7/2003 20:00
Sample Time

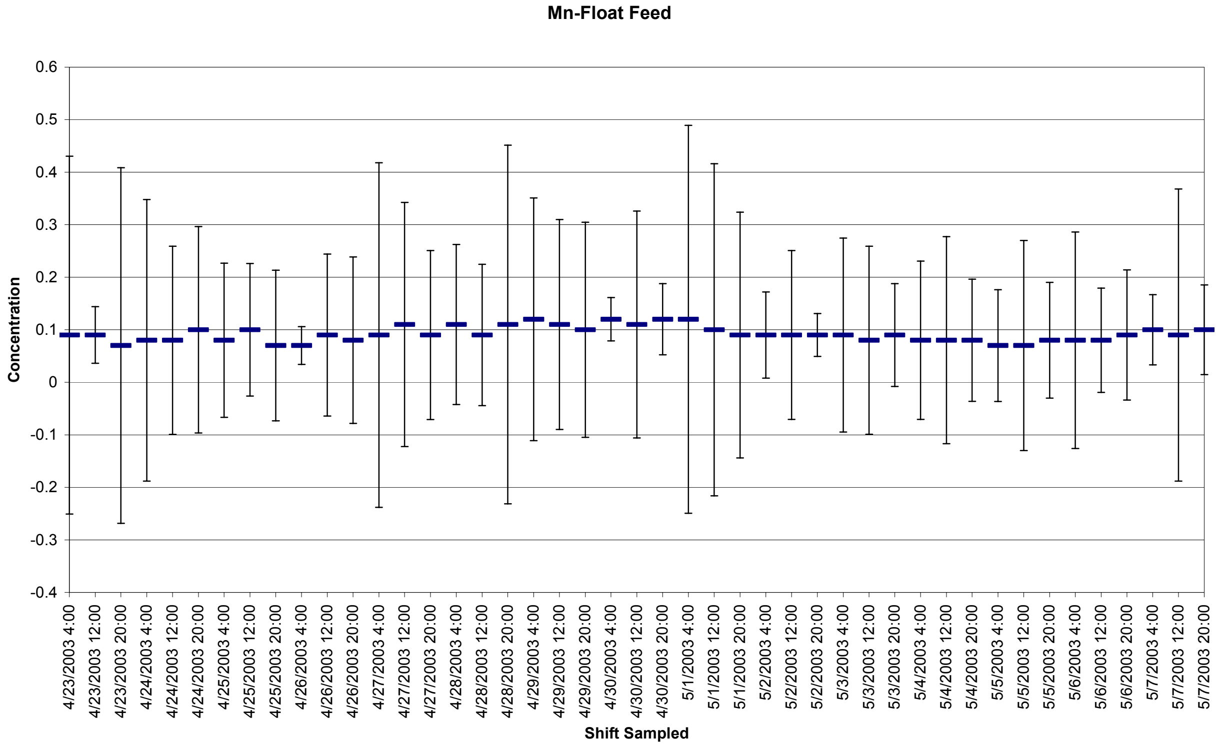


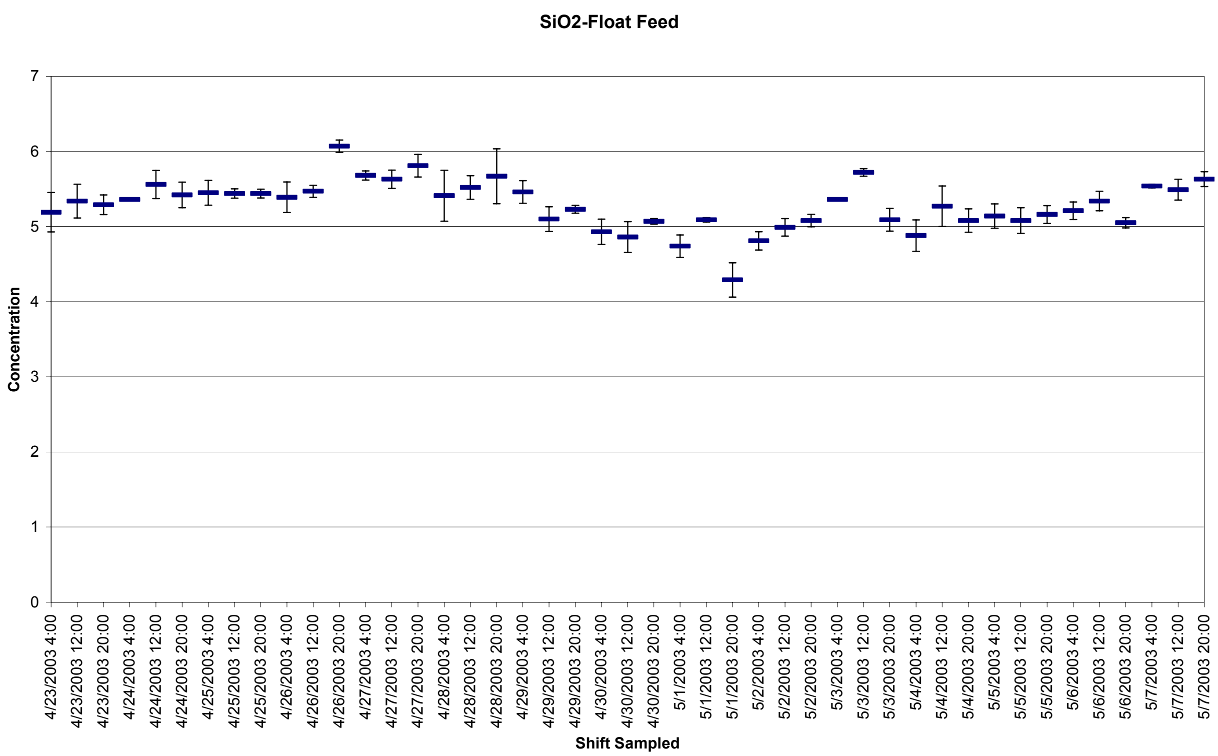
Another monitor of the feed to the flotation cells:



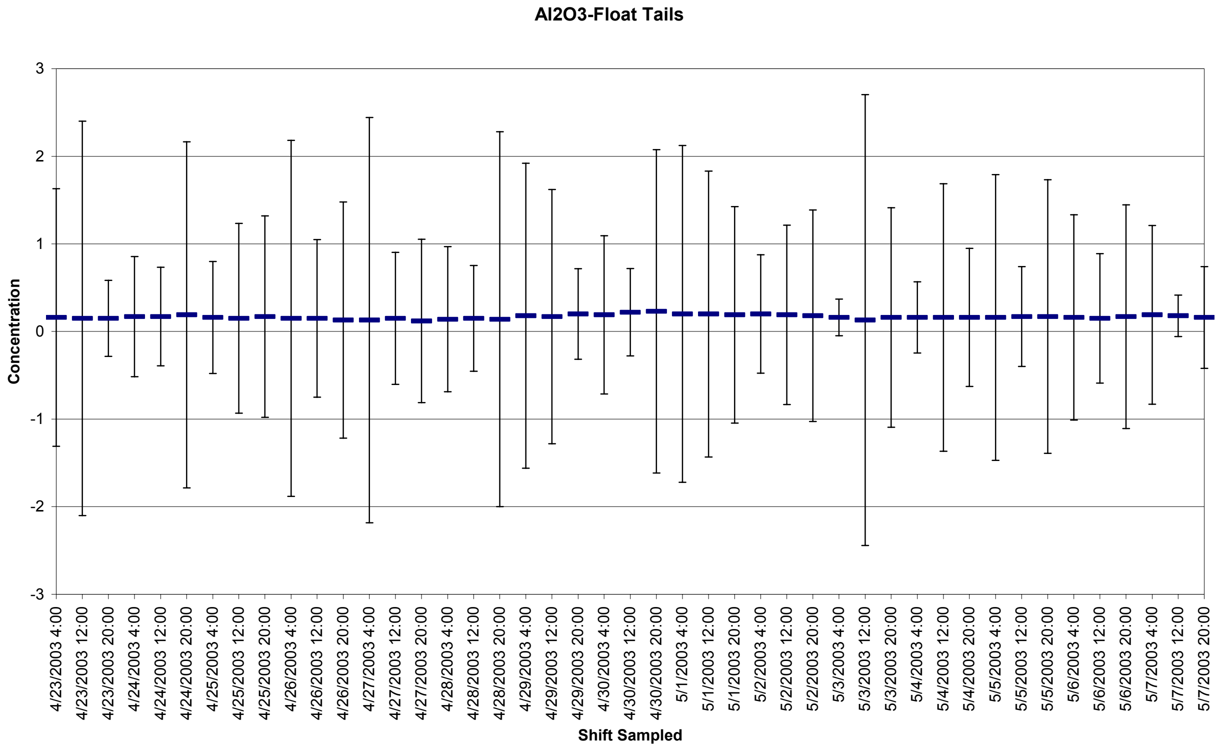

CaO-Float Feed
Concentration
Shift Sampled

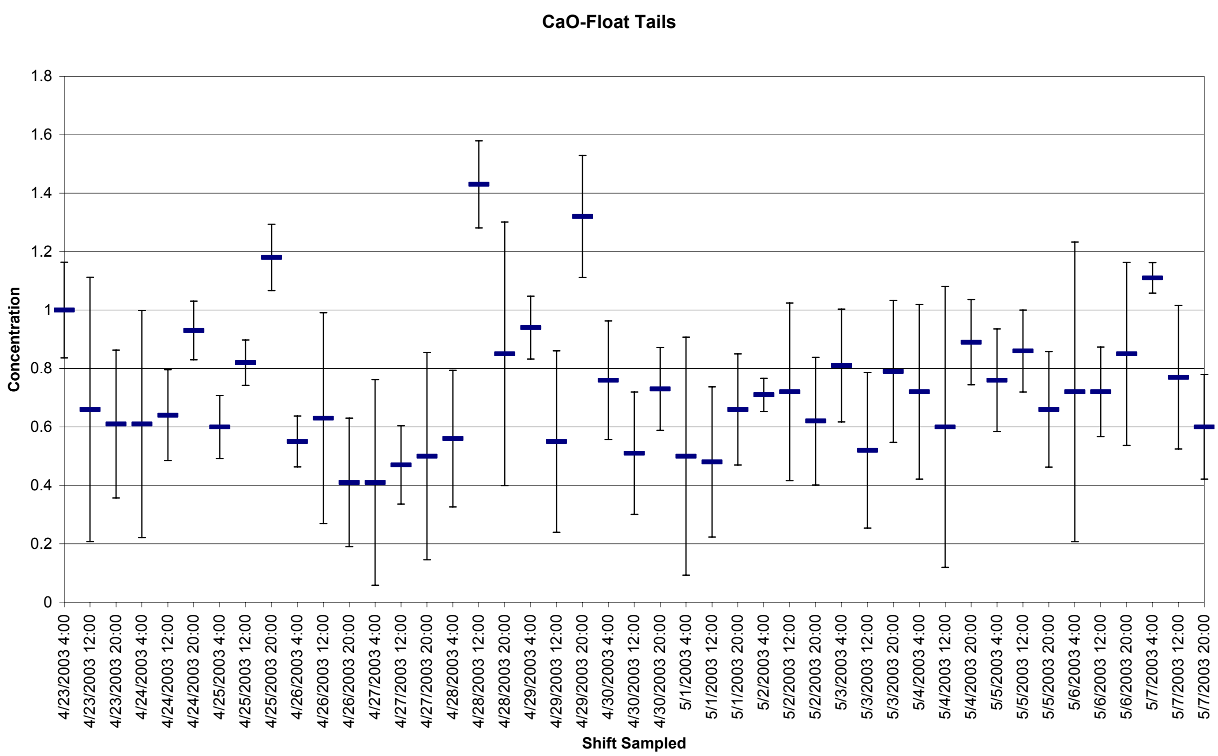

MgO-Float Feed
Concentration
Shift Sampled


Mn-Float Feed
Concentration
Shift Sampled
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4

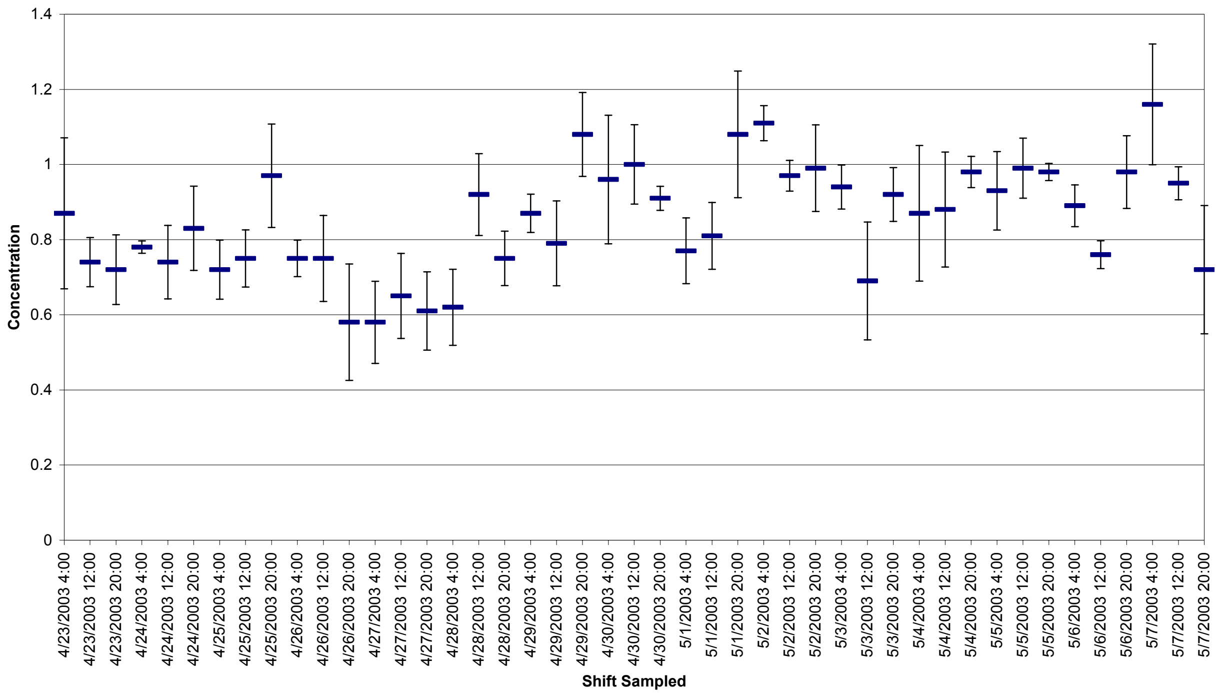

SiO2-Float Feed
Concentration
Shift Sampled
7
6
5
4
3
2
1
0

Monitor for the tailings from the flotation cells:

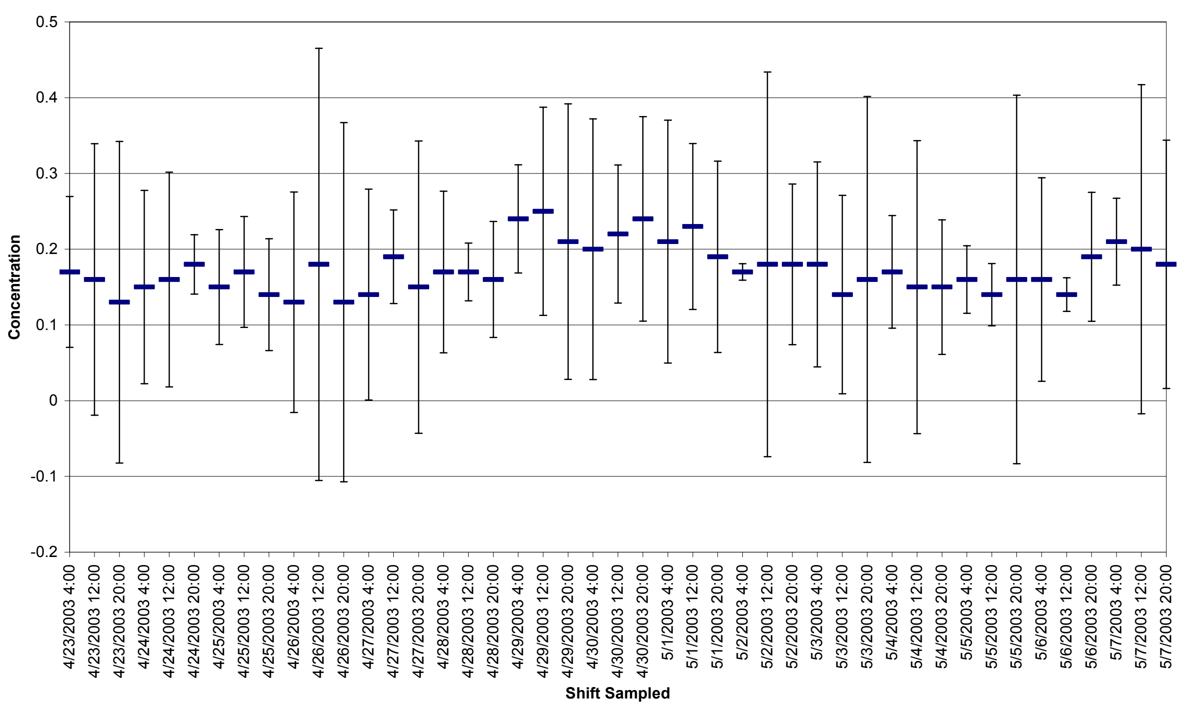


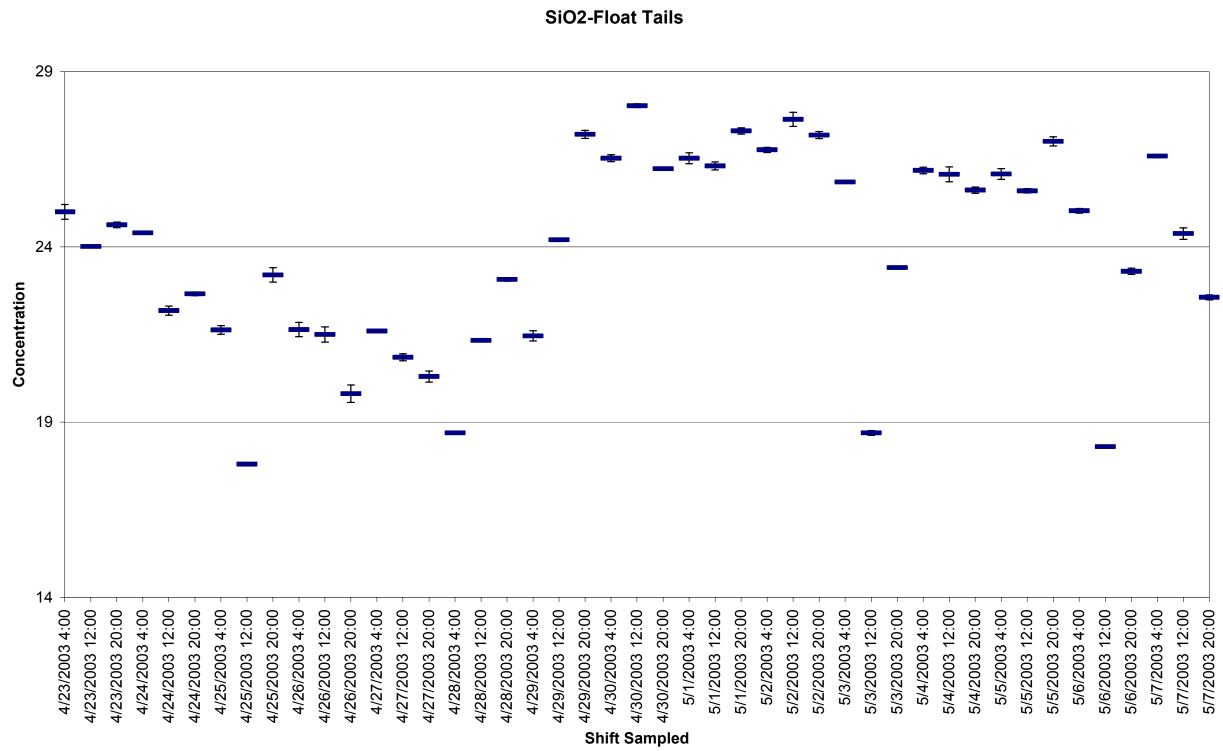


MgO-Float Tails

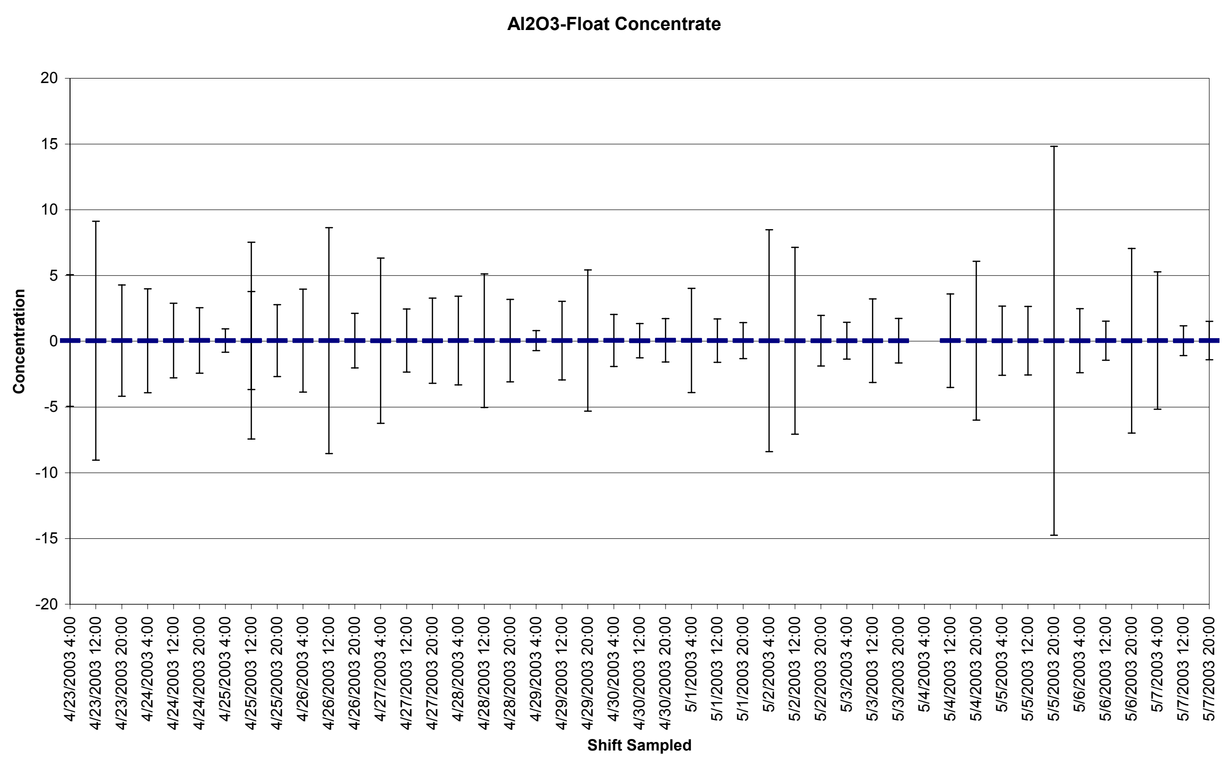


Mn-Float Tails

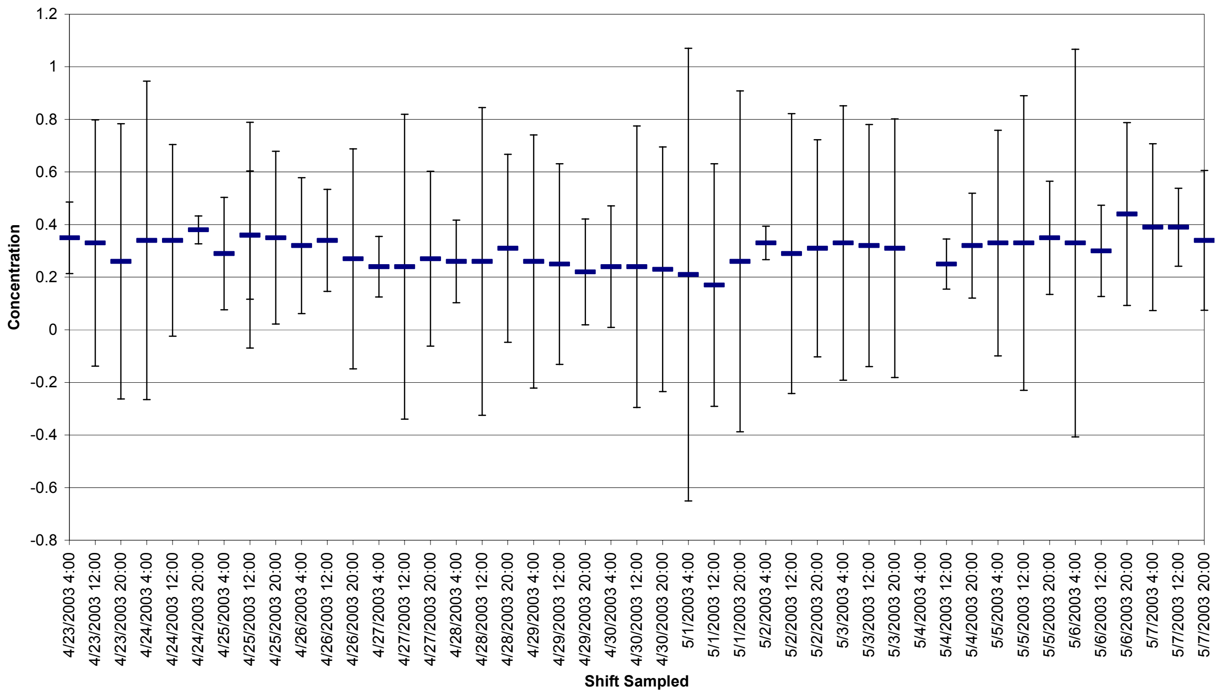




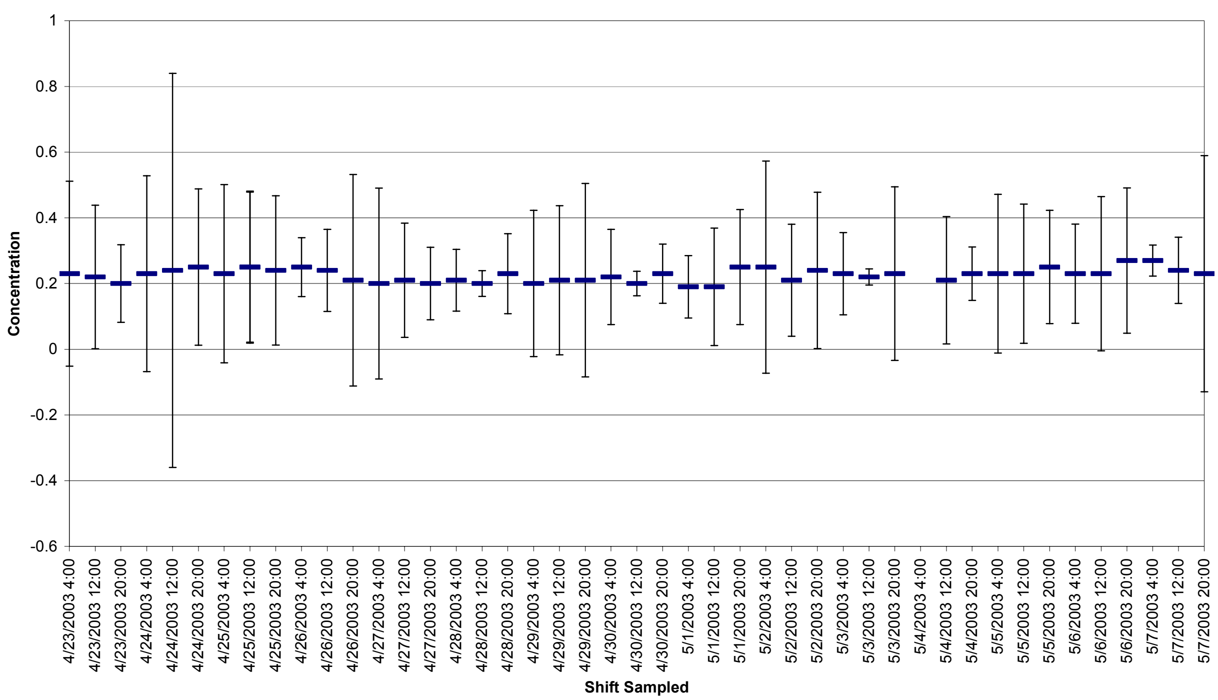
From the monitor for the concentrate from the flotation cells:

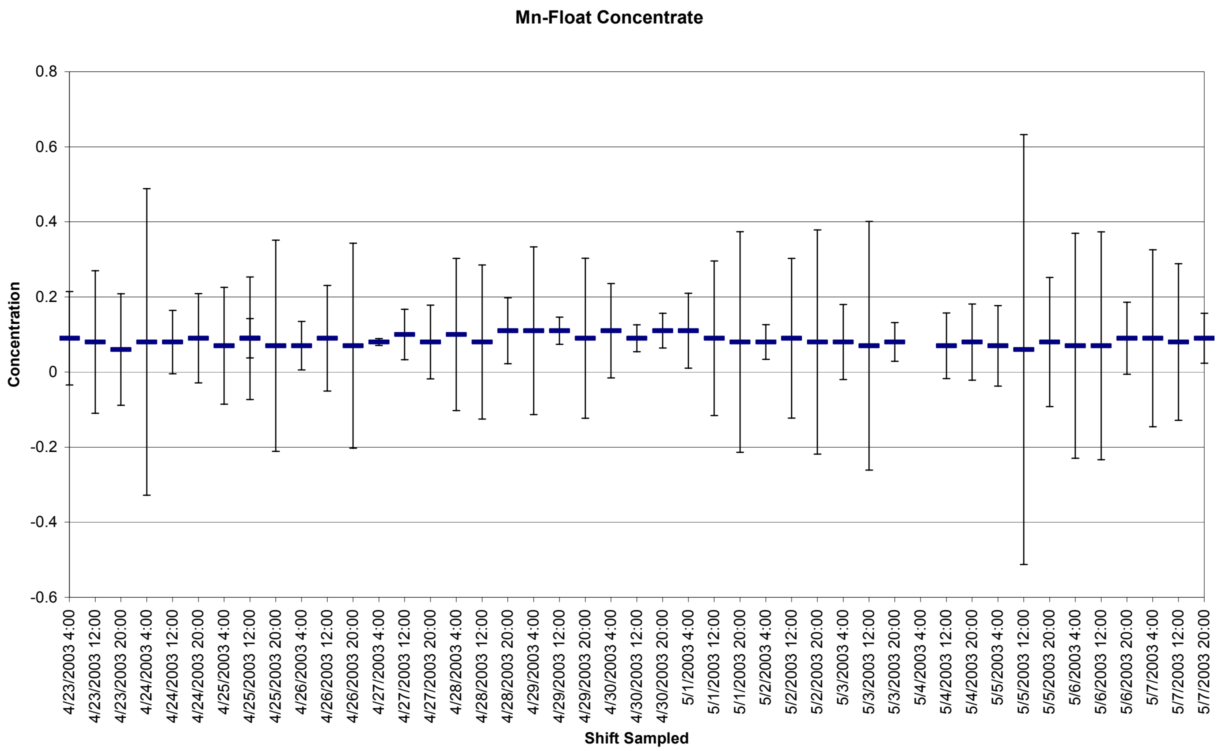


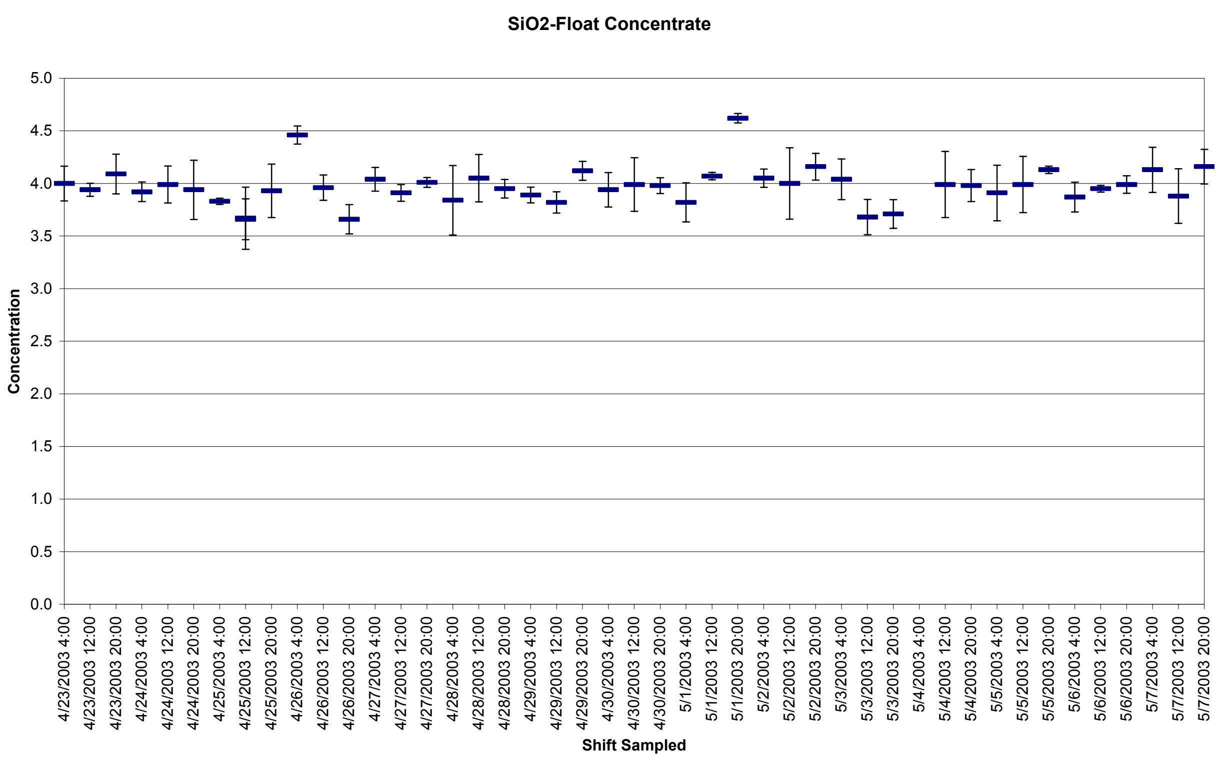
CaO-Float Concentrate



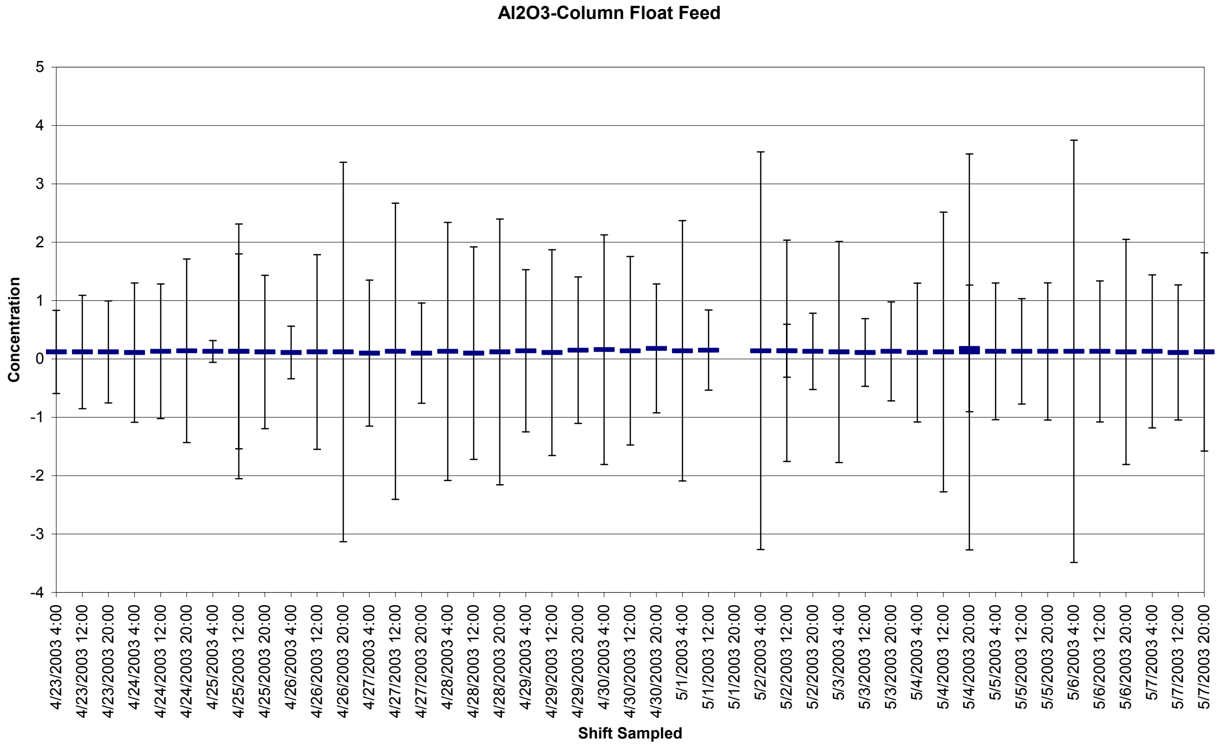
MgO-Float Concentrate

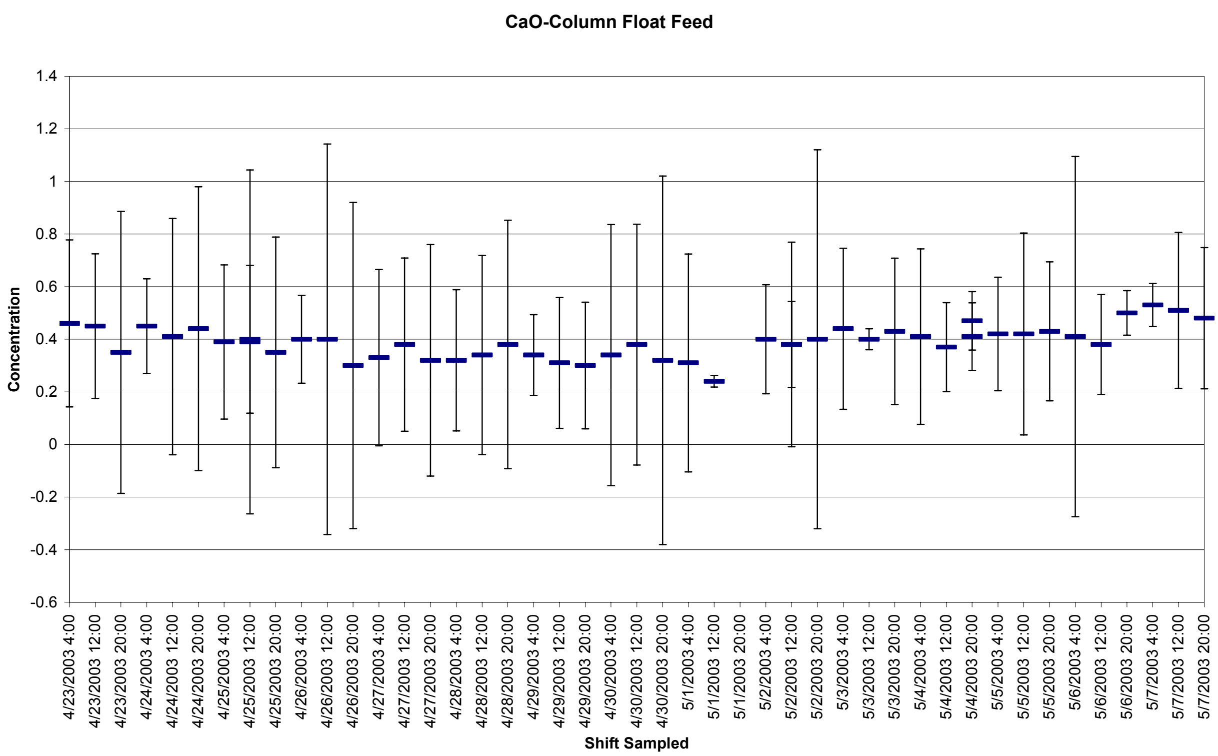


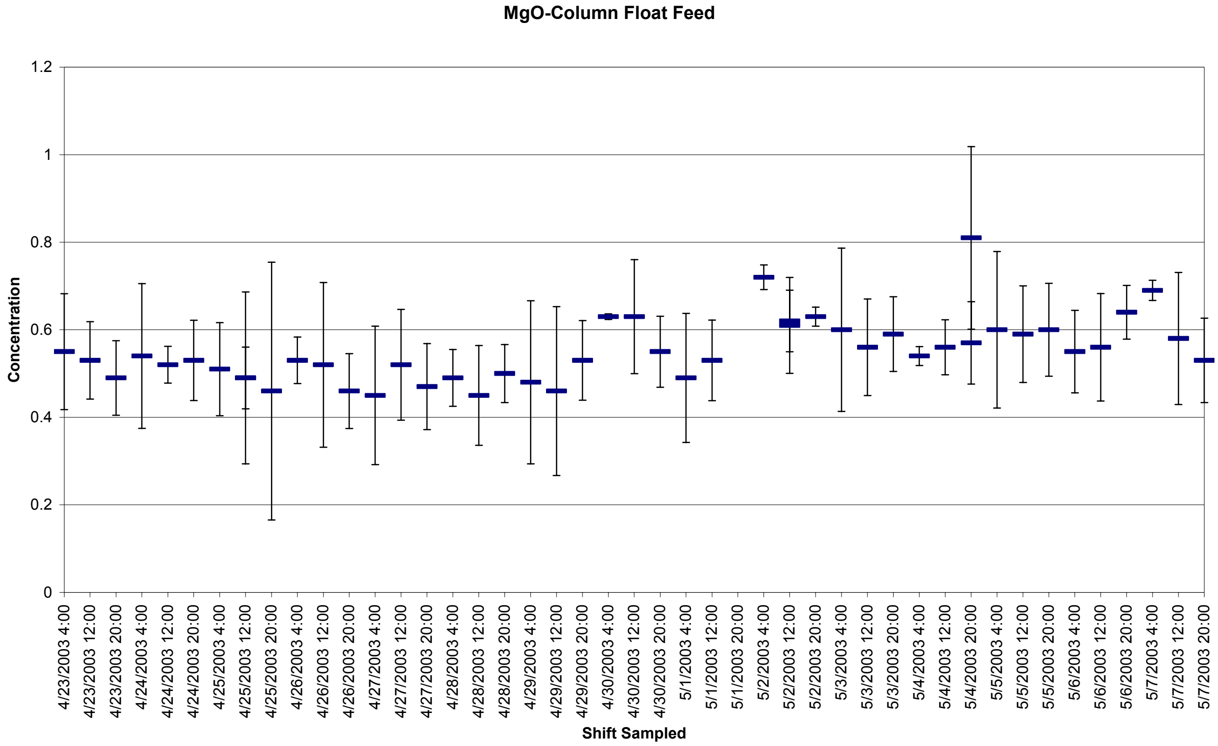

Mn-Float Concentrate
Concentration
Shift Sampled

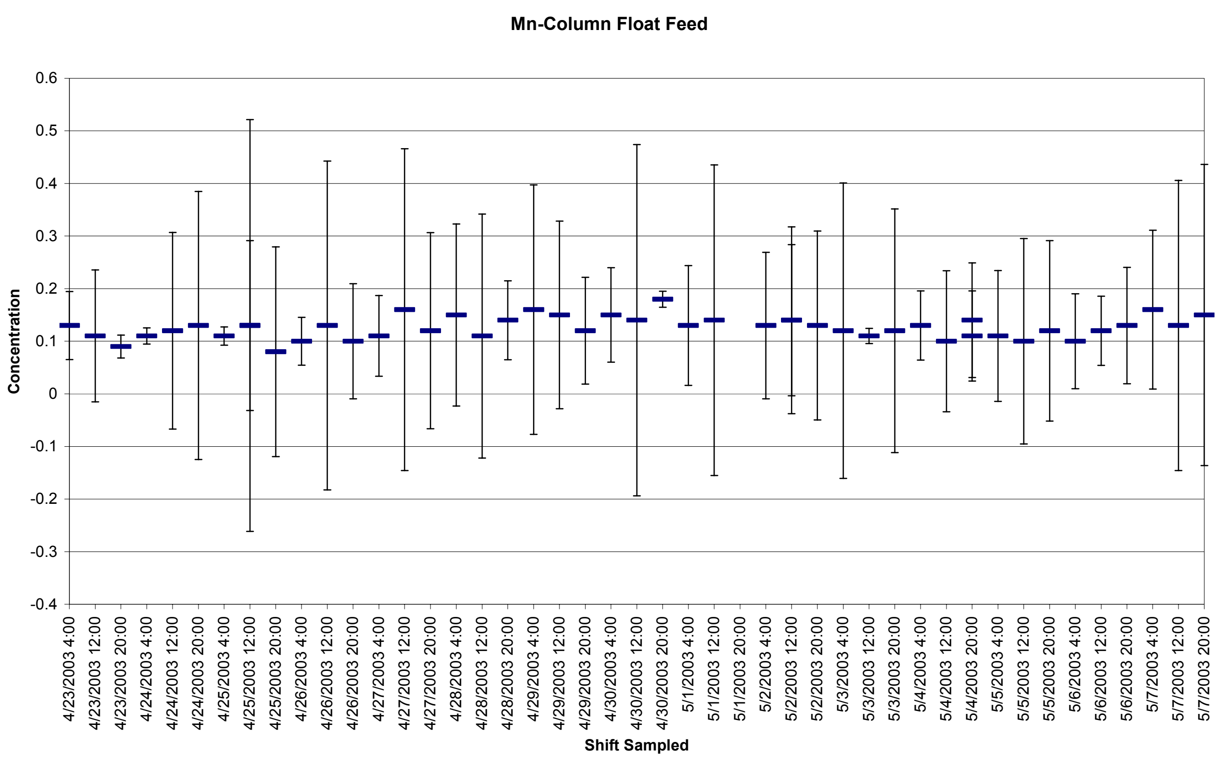

SiO2-Float Concentrate
Concentration
Shift Sampled

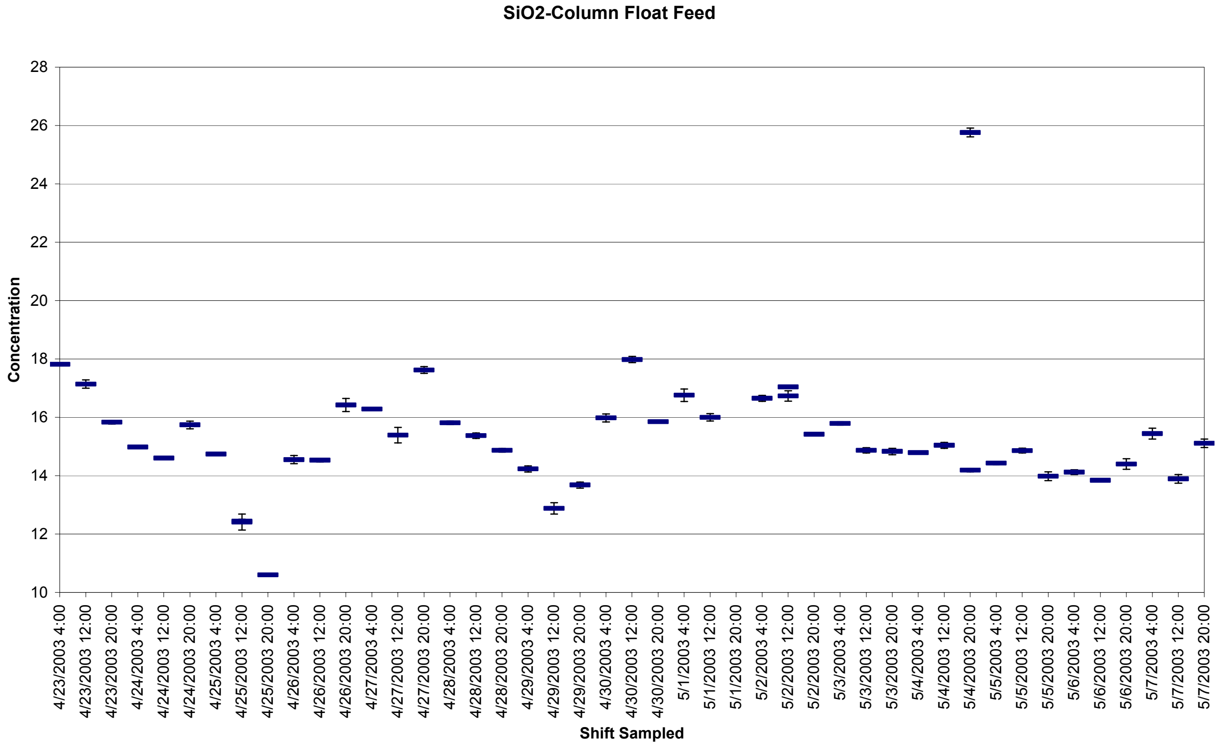
From the monitor for the feed to the flotation columns:



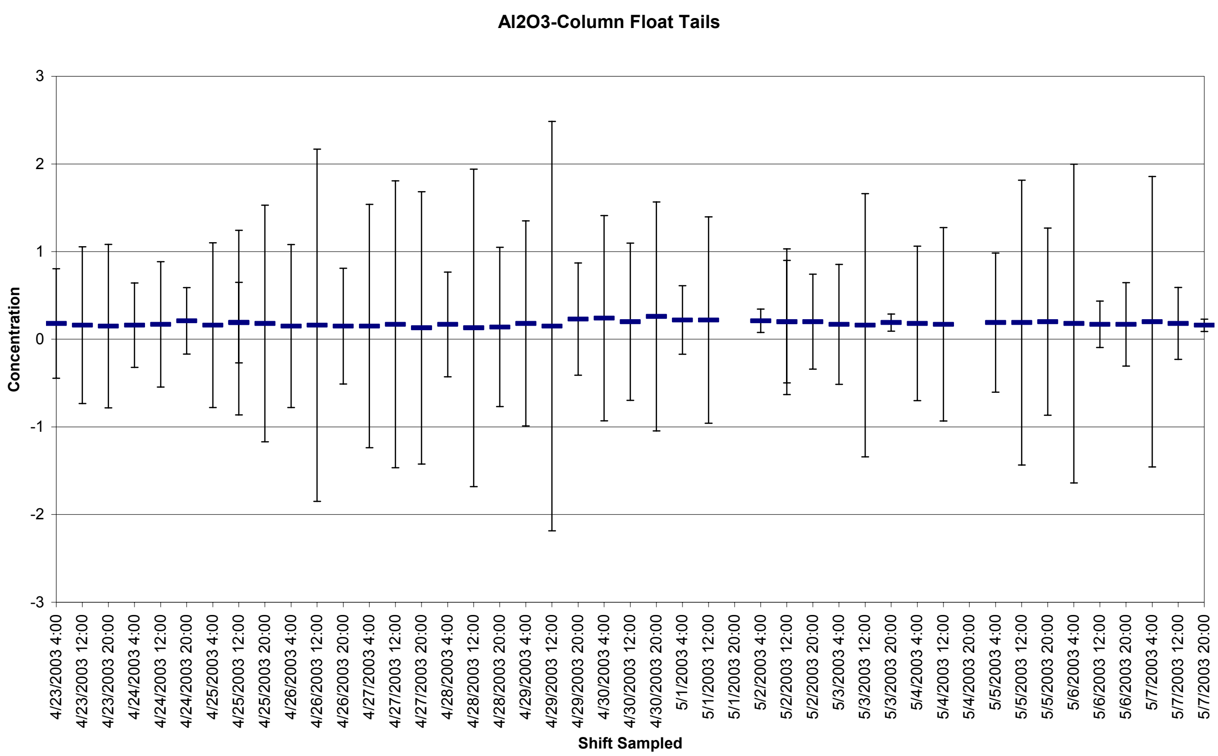


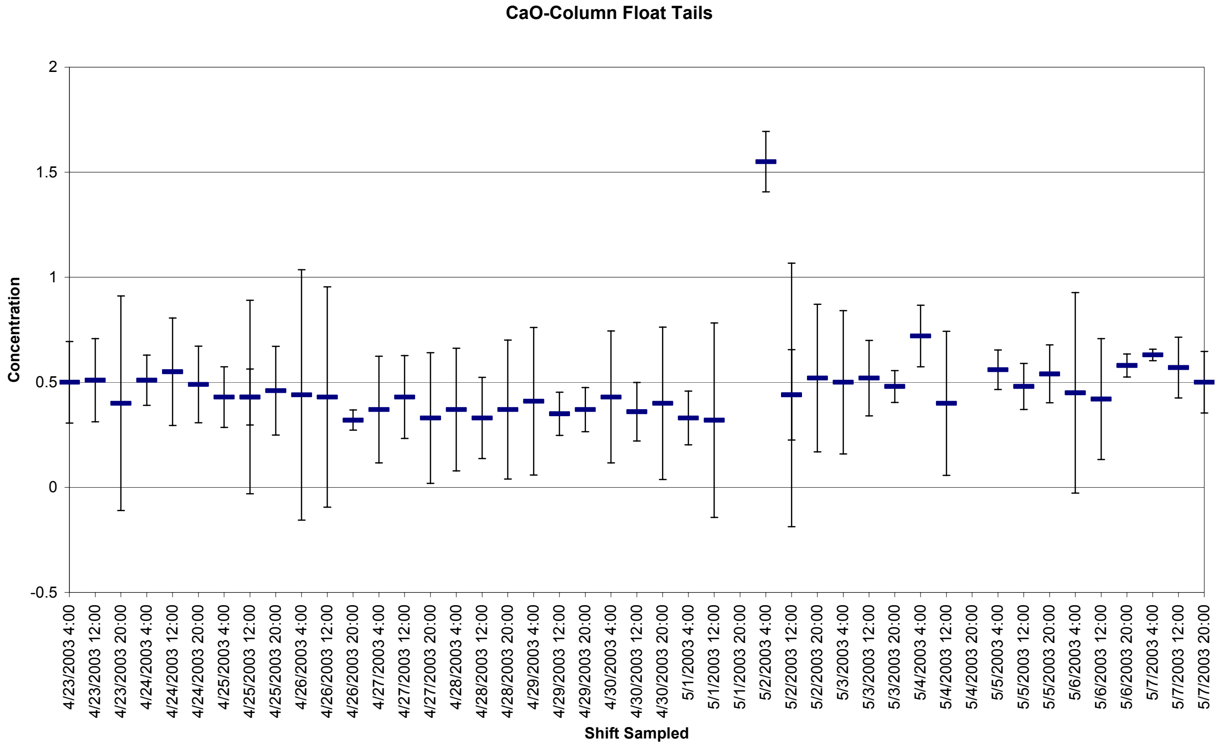

MgO-Column Float Feed
Concentration
Shift Sampled
0
0.2
0.4
0.6
0.8
1
1.2

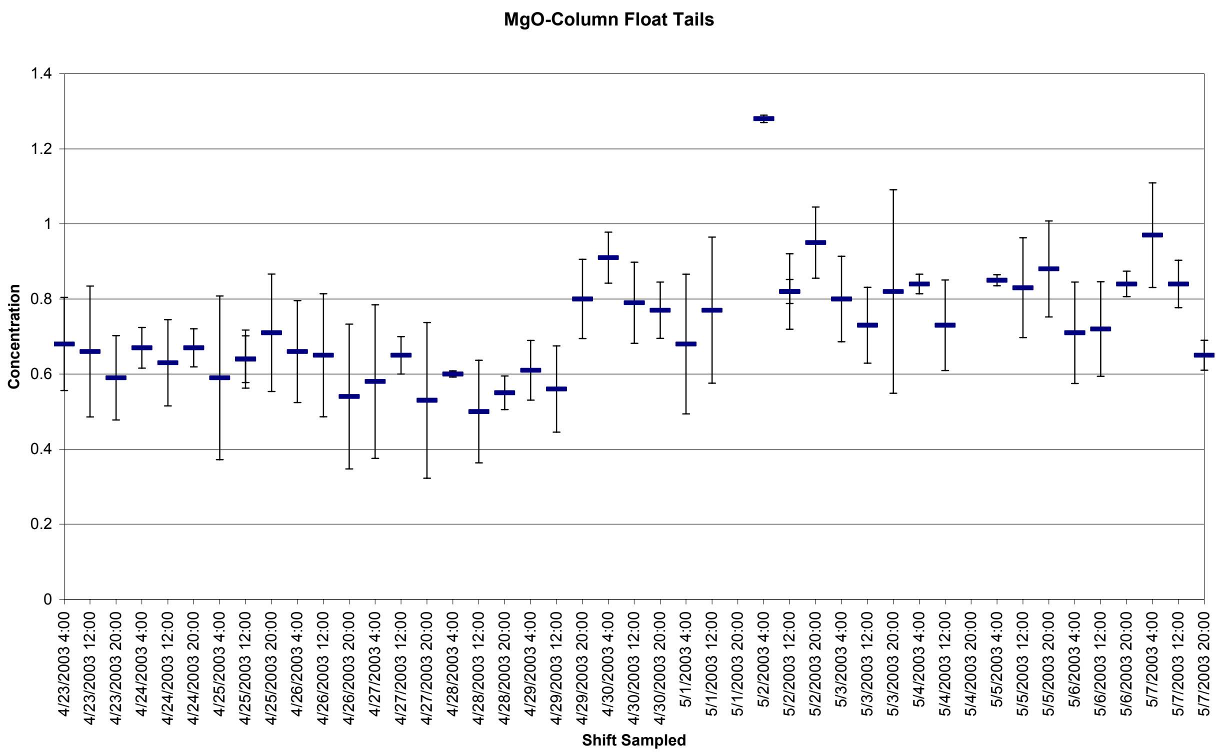

Mn-Column Float Feed
Concentration
Shift Sampled
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6

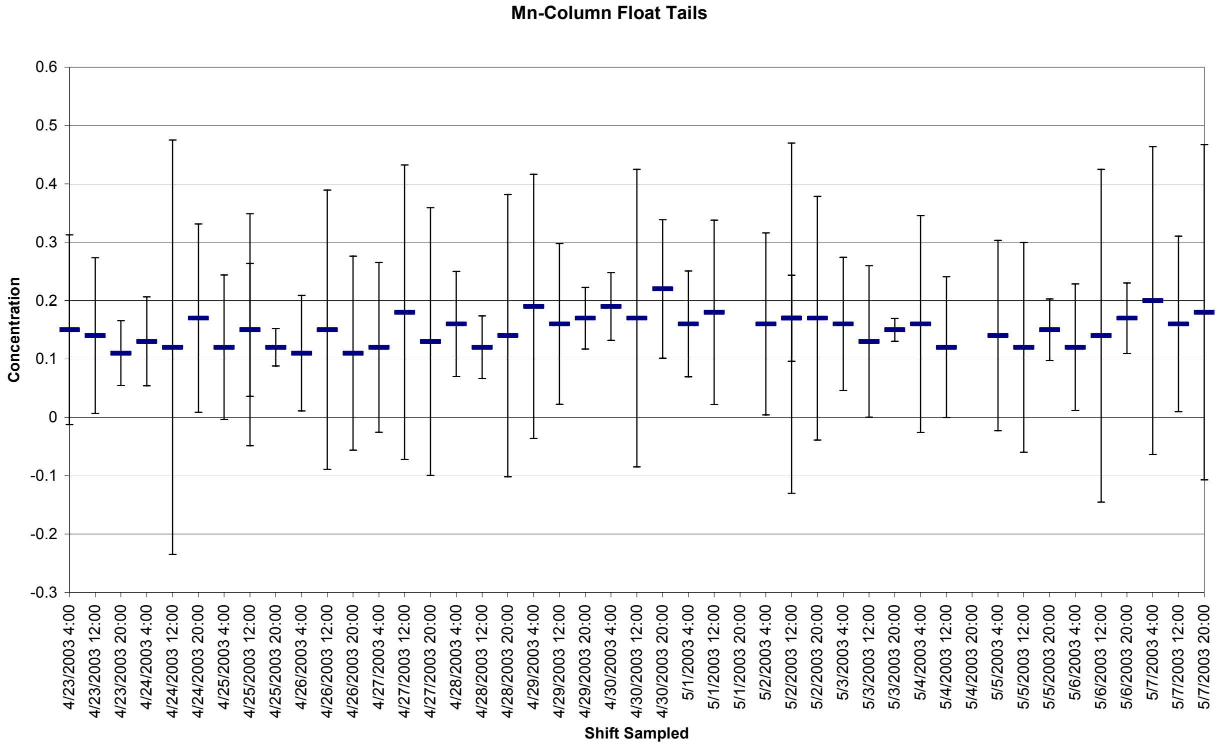


From the monitor for the tailings from the flotation columns:

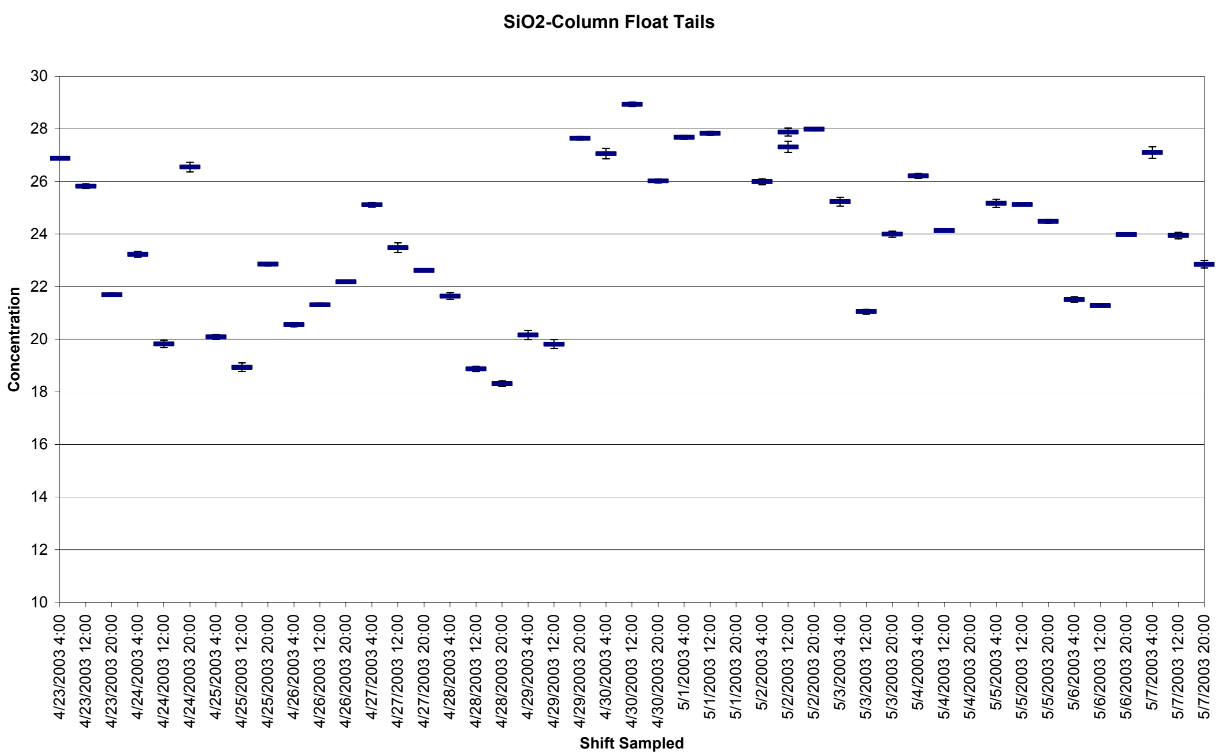



CaO-Column Float Tails
Concentration
Shift Sampled
2
1.5
1
0.5
0
-0.5


MgO-Column Float Tails
Concentration
Shift Sampled
1.4
1.2
1
0.8
0.6
0.4
0.2
0

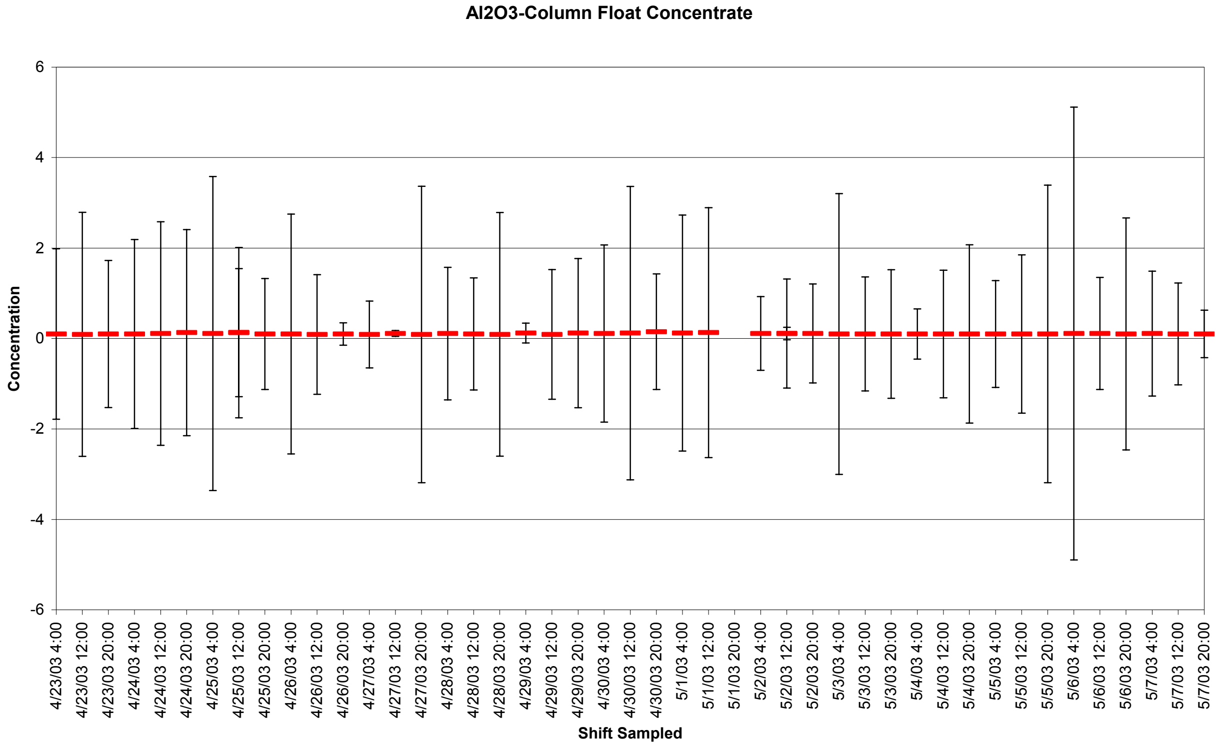


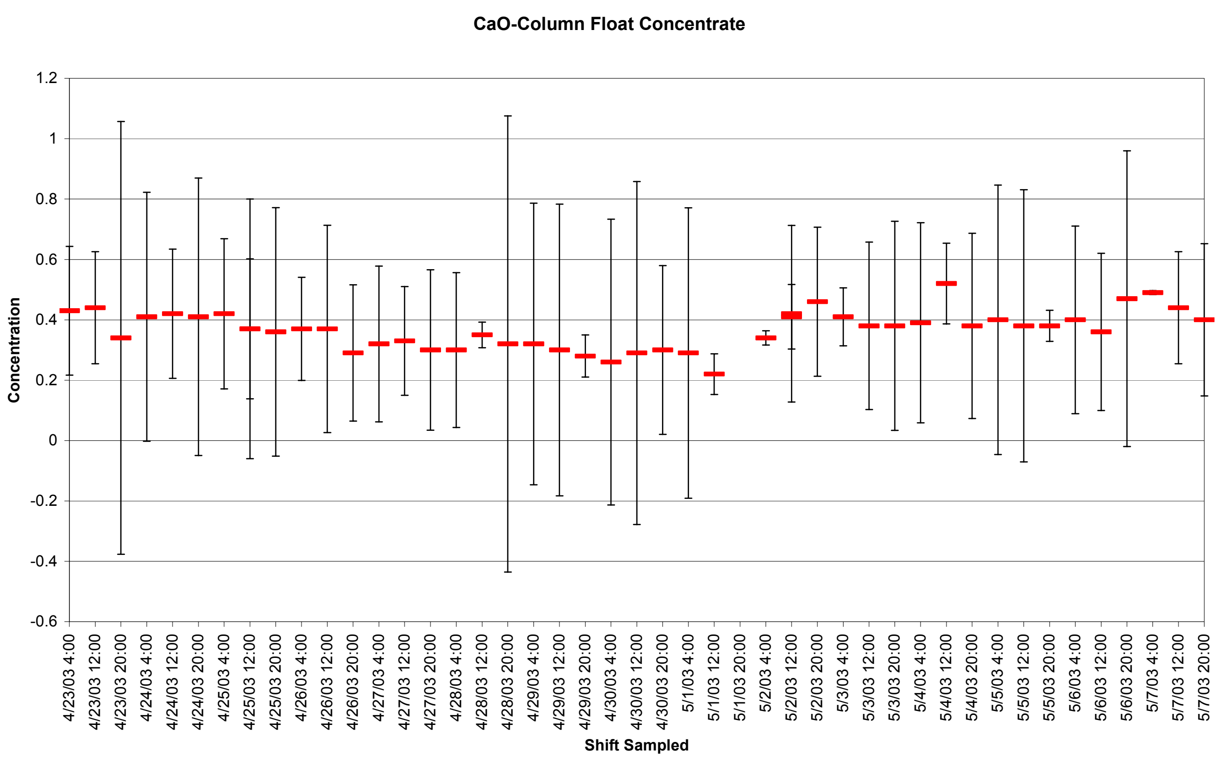
Mn-Column Float Tails
Concentration
Shift Sampled

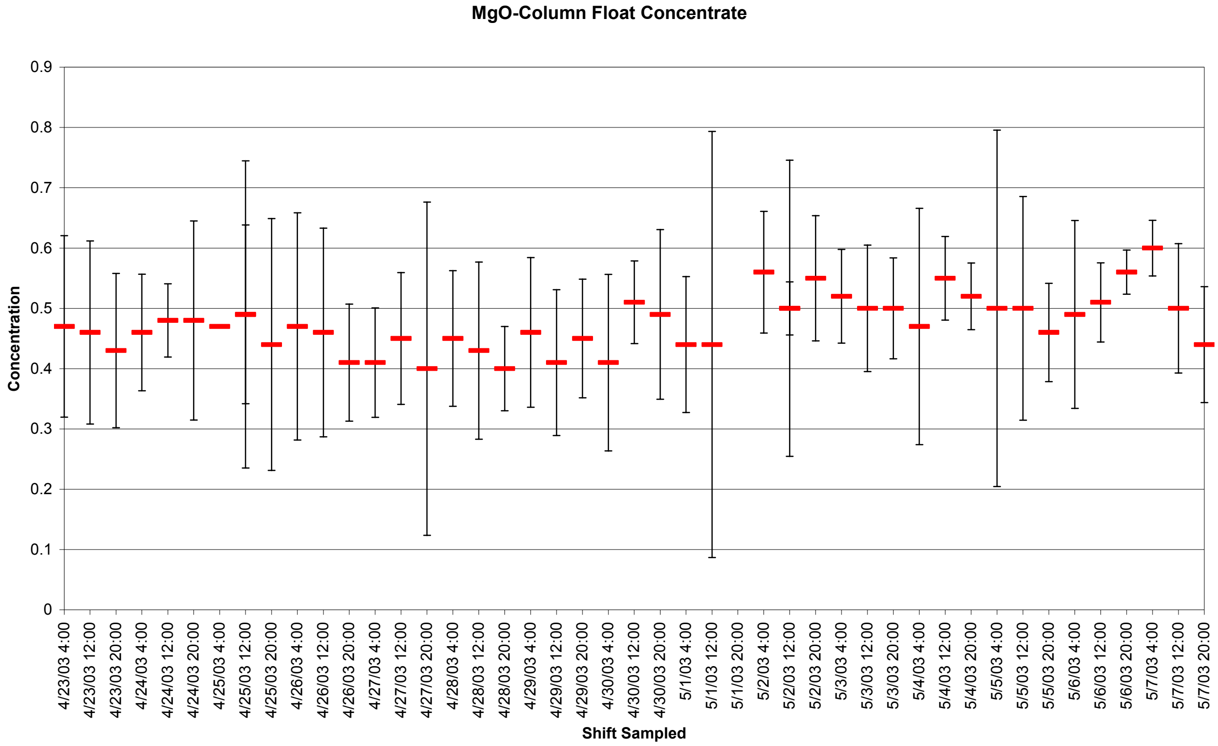


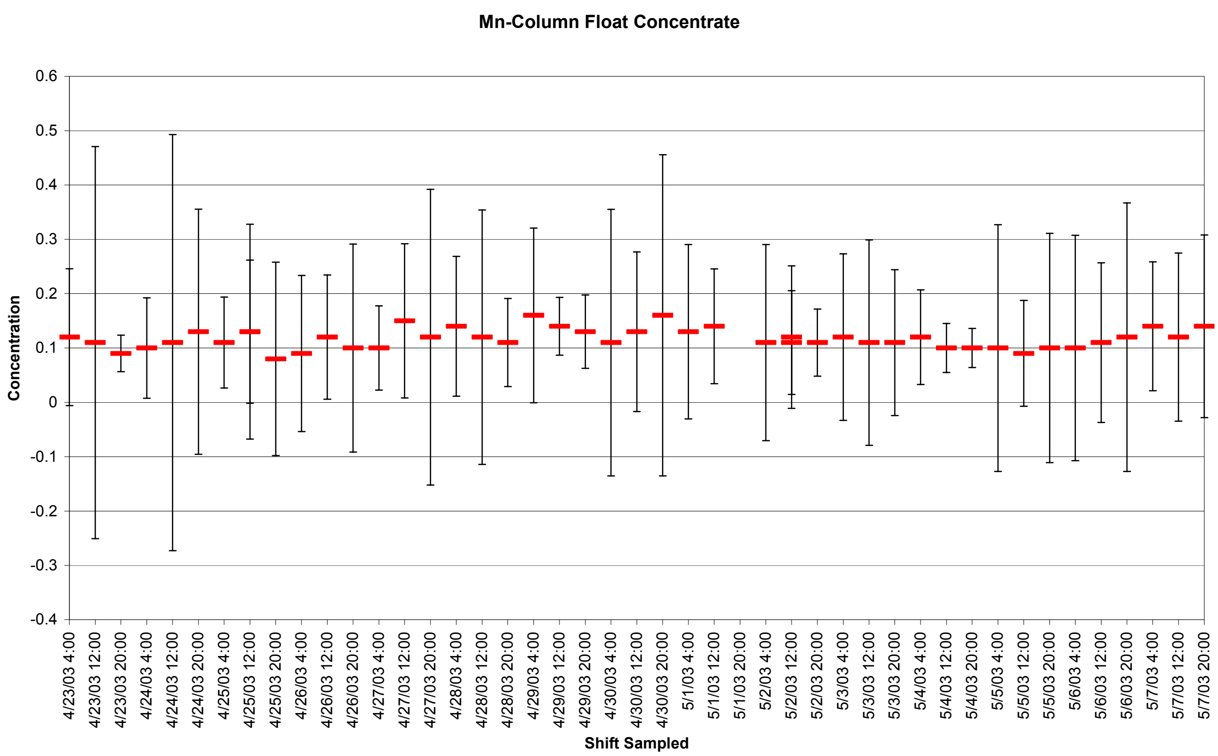
SiO2-Column Float Tails
Concentration
Shift Sampled

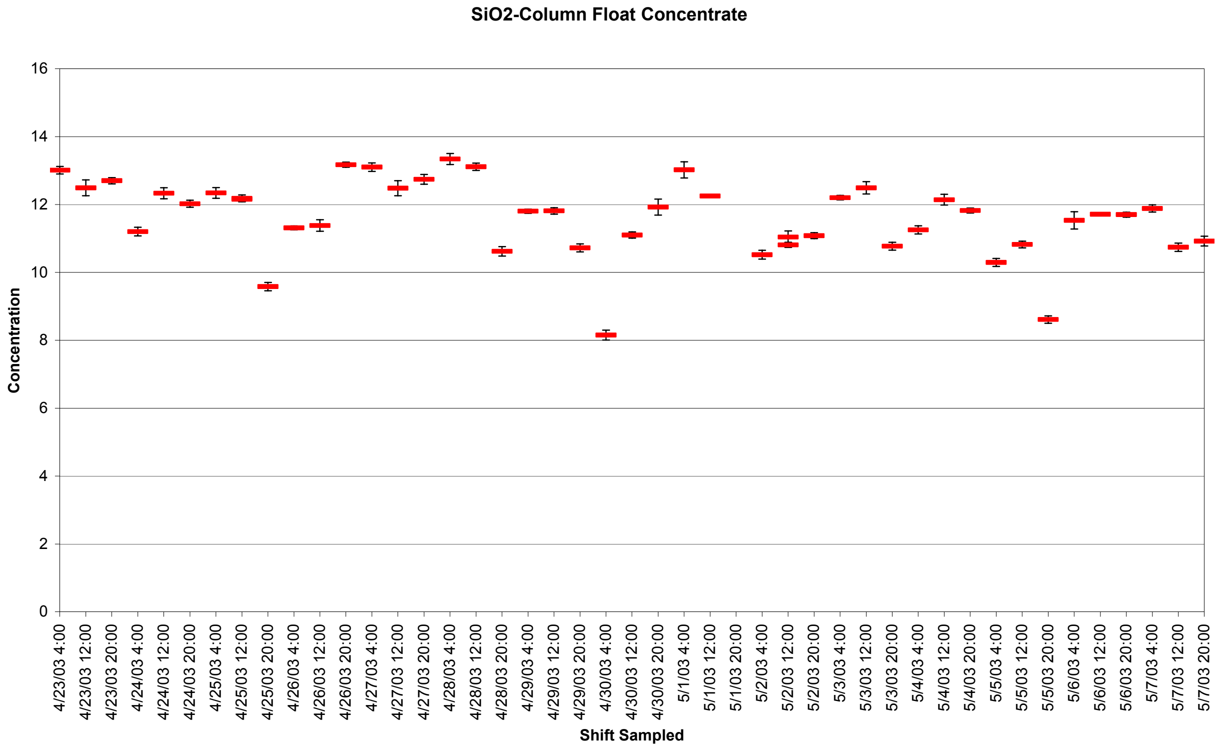
From the monitor for the concentrate from the flotation columns:






MgO-Column Float Concentrate
Concentration
Shift Sampled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
4/23/03 4:00
4/23/03 12:00
4/23/03 20:00
4/24/03 4:00
4/24/03 12:00
4/24/03 20:00
4/25/03 4:00
4/25/03 12:00
4/25/03 20:00
4/26/03 4:00
4/26/03 12:00
4/26/03 20:00
4/27/03 4:00
4/27/03 12:00
4/27/03 20:00
4/28/03 4:00
4/28/03 12:00
4/28/03 20:00
4/29/03 4:00
4/29/03 12:00
4/29/03 20:00
4/30/03 4:00
4/30/03 12:00
4/30/03 20:00
5/1/03 4:00
5/1/03 12:00
5/1/03 20:00
5/2/03 4:00
5/2/03 12:00
5/2/03 20:00
5/3/03 4:00
5/3/03 12:00
5/3/03 20:00
5/4/03 4:00
5/4/03 12:00
5/4/03 20:00
5/5/03 4:00
5/5/03 12:00
5/5/03 20:00
5/6/03 4:00
5/6/03 12:00
5/6/03 20:00
5/7/03 4:00
5/7/03 12:00
5/7/03 20:00


Mn-Column Float Concentrate
Concentration
Shift Sampled
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
4/23/03 4:00
4/23/03 12:00
4/23/03 20:00
4/24/03 4:00
4/24/03 12:00
4/24/03 20:00
4/25/03 4:00
4/25/03 12:00
4/25/03 20:00
4/26/03 4:00
4/26/03 12:00
4/26/03 20:00
4/27/03 4:00
4/27/03 12:00
4/27/03 20:00
4/28/03 4:00
4/28/03 12:00
4/28/03 20:00
4/29/03 4:00
4/29/03 12:00
4/29/03 20:00
4/30/03 4:00
4/30/03 12:00
4/30/03 20:00
5/1/03 4:00
5/1/03 12:00
5/1/03 20:00
5/2/03 4:00
5/2/03 12:00
5/2/03 20:00
5/3/03 4:00
5/3/03 12:00
5/3/03 20:00
5/4/03 4:00
5/4/03 12:00
5/4/03 20:00
5/5/03 4:00
5/5/03 12:00
5/5/03 20:00
5/6/03 4:00
5/6/03 12:00
5/6/03 20:00
5/7/03 4:00
5/7/03 12:00
5/7/03 20:00


SiO2-Column Float Concentrate
Concentration
Shift Sampled
0
2
4
6
8
10
12
14
16
4/23/03 4:00
4/23/03 12:00
4/23/03 20:00
4/24/03 4:00
4/24/03 12:00
4/24/03 20:00
4/25/03 4:00
4/25/03 12:00
4/25/03 20:00
4/26/03 4:00
4/26/03 12:00
4/26/03 20:00
4/27/03 4:00
4/27/03 12:00
4/27/03 20:00
4/28/03 4:00
4/28/03 12:00
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